Vol. XVI. — No. 8. August 1934.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[686]

Competition by roads, waterways and airways.

III.

We publish hereafter further information in connection with the competition to which rail transport is subjected; the two first parts appeared in the June and July numbers of our BULLETIN.

France.

Various alterations in the rates have recently been made in France by decree. The extent to which the decisions arrived at affect the rates, the reasons upon which they are based, and the results to be expected from them are dealt with in an article by Mr. Brion, Divisional Inspector on the Managing Committee of the Main Line Railways, published in the May, 1934, issue of the *Revue Générale des Chemins de fer*. The scope of this very interesting article is wider than its title — *French Railway Rates and their Evolution since the War* — would seem to indicate; it leads quite logically to an analysis of the economics of the reforms made necessary by the abolition, in actual fact, of the railways' monopoly and the growth of water transport and road motor transport.

The following extracts have been taken from Mr. Brion's article, and deal in particular with the decrees of the 30th December, 1933, and 19th January, 1934.

Rates alterations introduced by the Railways to meet the competition of other forms of transport. — Such competition is one of the causes of the Railways' deficit : changes in rates which they might have taken to retain their traffic until recently took a long time to get approved, and this delay often was an advantage to their rivals. They have only been given greater liberty, since the beginning of this year, by the decrees of the 30th December, 1933, and 19th January, 1934. We will begin by giving particulars of the different steps the Railways took before these decrees came into force, the main clauses of these decrees and the results to be expected from them will be given subsequently.

a) *Steps taken before the decrees of the 30th December, 1933, and 19th January, 1934.* — The Railways endeavoured to regain the traffic they had lost, or to keep the traffic they were likely to lose, by altering the rates, either by reducing the charges and making special prices, or by quoting inclusive rates; rates reductions were exceptional : they were applied as a rule between points where competition was especially severe. The Railways have been most successful in retaining traffic

by inclusive rates. Such rates were granted in particular in the case of certain industries which were considering doing their own transport work. Beside these reduced or inclusive rates, consignors sometimes undertook to send all their goods by rail for an agreed period, as we have already stated, or bonuses proportional to the tonnage sent by rail were granted to the consignors.

The next step to be taken by the Railways to meet competition was to make provision in the regulations for « handling the traffic in the most convenient way for the consignor and as fast as by motor services », for door to door collection and delivery on the one hand, and speeding up delivery by reducing carriage delays.

Among the first of these measures may be mentioned first of all, in the case of parcels traffic between large centres, the facilities given to agents to group consignments with a system of rebates according to tonnage or of premiums given on consignments sent regularly, and in the case of large consignments and goods of all kinds, the provision of containers forming a part wagon load. The Railways have also been led to make agreements, with their road motor subsidiary companies, or through these with some road motor hauliers, for collecting and delivering goods, the actual carriage from one town to the other being by railway in full wagon loads; some railways, on the other hand, give a door to door service for both fast and slow goods with their own cartage services.

Finally some of the Railways have introduced rates applying to certain goods, such as food stuffs for the Paris Markets, which include delivery by motor lorry and the return of empties to the loading station.

In the second group we must mention the introduction of express parcels services whereby parcels are collected and delivered by railway in less time than by road, the general reduction in transit times and the introduction of accelerated services with guaranteed delivery within a specified time.

Finally, a third step was covered when the Railways endeavoured to adapt, to some extent, their rates to those of road motor hauliers by introducing a scale of charges based on the wagon-kilometre.

We will now give some details of the provisions of these last three measures.

General reduction of transit times. — The new regulations governing transit times approved on the 20th July, 1932 (1) include the following chief improvements :

In the case of fast traffic :

— the parcels trains workings are taken into account when calculating the transit time for parcels traffic deliveries (formerly the specified time for such traffic depended upon the time taken by the first passenger train to the same destination, express trains and some mail trains being excluded. Express goods traffic consequently did not as a rule profit by the parcels trains);

— the introduction of very short times for express goods traffic as between certain places; this was especially advantageous when the goods were conveyed over several railways (formerly in such cases the transit time required by such transfer from one system to another was frequently increased by more than 6 hours);

— the suppression of the twelve hours notice (six hours at large stations) in the case of perishable goods, when the consignor required these to be sent by the fastest route.

In the case of ordinary goods traffic :

— the abolition or reduction of any

(1) These measures which were submitted for approval on the 15th September, 1930, were only approved *two years later*, on the 20th July, 1932.

extension of the transit time exceeding five days allowed in certain tables of rates;

— the introduction of shorter transit times for consignments of al least 2 000 kgr. (4 400 lb.) coming under the general goods rates, for traffic sent in full wagon loads or consignments of at least 5 tons, coming under the special goods rates applicable as between certain named stations [formerly the minimum transit time to distances under 125 km. (77 1/2 miles) was four days, and even 5 to 6 days if two railway systems were involved].

Thus in the case of *express goods* a consignment to be carried 450 km. (280 miles) handed over on day A two hours before the booked departure time of the last train of the day had to be delivered, according to the old timing, on day E within two hours of the arrival of the train by which it was carried. By the new formula, the goods must be at the disposal of the consignee on day D at the latest, at the same hour as they were handed over on day A.

In the case of *slow goods*, the result of applying these regulations has been that consignors save on the old times for complete wagon loads or consignments exceeding 2 000 kgr. (4 400 lb.) 1 to 6 days for goods carried at the general rates, and 4 to 9 days for goods at special rates; when dealing with traffic over two or several companies' lines, 1 to 8 days for goods at the general rates and 4 to 13 days for goods carried at special rates.

Speeded-up traffic with guaranteed delivery times. — Another reform which should be of great advantage to manufacturers and traders is the introduction of faster ordinary goods services with guaranteed date of delivery. As the date of delivery in the case of ordinary goods traffic was not guaranteed, all traders had to keep large stocks of goods and raw materials so as to be able to meet trade or manufacturing requirements, frequently at great inconvenience.

According to the new tariffs, which have been in force since the 1st October, 1932, goods must be placed at the disposal of the consignees within 1 to 5 days, as a general rule, according to the distance, in the case of certain services between commercially important centres. The new regime applies to ordinary goods traffic sent in consignments of at least 4 000 kgr. (8 800 lb.) or by complete wagon loads, the loading and unloading being done by the consignors and consignees.

The railways charge consignments of this sort a supplement equal to 10 % of the total charges. If the guaranteed time is exceeded, the railway has to pay a compensation double the 10 % supplement.

For example, the time taken to send goods coming under this scale of rates from Tours to Paris is one day (instead of 5 to 6 days for goods by ordinary slow goods trains); from Nancy to Paris, 2 days (instead of 7 to 9 days); from Bordeaux to Paris, 3 days (instead of 5 to 7 days); from Strasbourg to Lyons, 4 days, (instead of 7 to 9 days); from Marseilles to Dunkirk, 5 days (instead of 9 to 11 days).

In order to complete these measures the Main Line Railway Companies submitted to the Ministry, for approval, various proposals including : the suppression, in the case of both fast and slow goods services, of any time allowance in the case of goods passing through a joint station; the reduction by half, for both fast and slow goods, of the time allowed in the case of railways serving the same place (other than Paris) with separate stations connected by rail; finally the use of a new formula for calculating the transit times for ordinary goods traffic, which in the future will be calculated on a basis of 24 hours

per 200 km. (124 miles) (1) or part thereof, whereas formerly the basis was one day per 125 km. (77 1/2 miles) or per 200 km. (124 miles) according to the railway.

Special rates based on the wagon-kilometre. — In addition to the special rates and the general improvement in dealing with the traffic, the Railways felt that the motor competition problem might be solved by introducing rates based on the wagon-kilometre between given places, such rates not depending on the value of the goods transported, and including faster times easily calculated by a simple formule.

So that consigners could take advantage of these rates, which came into force on the 1st March, 1933, the Railways hired out open and covered wagons for periods of three months, which could be extended; each journey made by the wagon, whether loaded or empty, is then charged at a flat rate per kilometre run, the nature and weight of the goods transported not being taken into account.

The charges were based on the rates of road hauliers and included the terminal charges (loading, unloading, collection or delivery). A minimum fee per consignment is charged however to force consignors using the special rates to cencentrate on average and long-distance traffic only, thus leaving the short-distance traffic to the motor hauliers, as well as the collection and delivery of goods round the important stations, who logically should deal with this work.

This rating system, which gives the public a real « rail-lorry » service, has the following advantages for the railways :

It encourages groupers to give up road transport in the case of long-haul traffic and to collect goods from all round important centres, and should have the effect of restoring motor transport to its proper role, i.e. that of collecting traffic for the railway. On the other hand, as the rates are the same for loaded and empty running, the consignors try to avoid light running; up to the present, in fact, one of the reasons why the railway has been able to hold its own against motor competition was that lorries on long-distance work were not always assured of a return load, but they are actively organising themselves for this purpose.

As yet this wagon-kilometre rate has not been very extensively used; nonetheless in cases where the existence of traffic in each direction would have facilitated road transport competition, it has enabled the railway to keep, or recover, traffic it might have lost.

On the whole, the different measures which we have reviewed have a somewhat limited scope; they have been able to give satisfactory results between certain places or in certain traffics, but they have not prevented increased competition against the railway.

The first obvious reform was to give the Railways greater liberty in the matter of approving new rates; this was the object of the decrees of the 30th December, 1933, and 19th January, 1934, the contents of which we will now deal with.

b) *Decrees of the 30th December, 1933, and 19th January, 1934.* — For some time the Railways had asked the Public Authorities to relax part of the stringent regulations to be complied with to get new rates approved, and to allow them greater freedom in fixing these rates.

They pointed out that the procedure to be followed in preparing rates placed the railway in a position inferior to that of its rivals; first of all the formalities in connection with the sanctioning of

(1) This reduction in transit time is the subject of a clause in the decree of the 19th January, 1934, which will be dealt with later on.

the rates were a source of weakness, as competitors were enabled to learn the railways' proposals and so knew exactly what efforts they must make to get the traffic; in addition, the long time such approval required deprived the railways of the advantage of retaliating by a sudden application of the rates; proposals to alter the rates, though made in good time, were frequently ineffective as they were only approved after competition had fully established itself and was difficult to oust. Finally the railway rates, once settled, could not be altered, while competing hauliers could modify theirs according to the law of supply and demand, raise them when trade is busy, increase their profits and pay off their stock, and, contrariwise, lower them in periods of crisis, so that their staff and stock are not idle during such periods, the only drawback being that sinking fund contributions have to be held over for the time being.

The decrees of the 30th December 1933, and 19th January, 1934, met the requirements of the Railways to a great extent; first of all the decree of the 30th December, 1933, gave more flexibility to the procedure for the approval of rates, by agreeing, as we mentioned at the beginning of this study, to the railway rates for both normal services and road motor services replacing train services being applied provisionally by the railways prior to official publication.

Furthermore, rates which had been lowered can be restored to their old level after three months' time instead of one year's.

The same decree makes provision for maximum and minimum rates, the railways being free to fix the rates within these limits, subject to 15 days' public notice.

In addition, it lays down that in the case of traffic going by railway only part of the way, the Minister of Public Works can authorise rates applicable to the through journey only, such rates not being necessarily equal to the total amount of the part journey by rail plus the part journeys by other methods of transport.

Finally it provides a much simplified method of fixing the rates, as it lays down that in the case of road services set up by the railway to replace trains, and operated by a contractor receiving no other remuneration than the charges he collects from the public, the railway need not submit the maximum and minimum rates for Ministerial approval; such rates are subject to the condition that they have been made public by means of posters one month before they are put into force.

The decree of the 19th January (1) completed these arrangements by allowing the railways to simplify the method of collecting their charges, and to fix the rates according to other bases than the number of kilometres, or the weights, as laid down in the regulations. This latter decree specified that the amounts should be fixed according to the number of kilometres and that if the distance was less than 6 km. (3.7 miles) it should be counted as 6 km.; also that fractions of weight should only be counted per hundreth of a ton or per 10 kgr. (22 lb.).

In addition important changes were made in the regulations in regard to consignments and transport times.

As regards *forwarding consignments*, the regulations obliged the Railways to despatch the goods in the order in which they were received, without regard to the tariff conditions to which they were subjected; in order to remedy this abnormal situation, the decree of the 19th January, 1934, lays down that the obligation of despatching goods for the same destination in the order they were booked in only applies to goods carried under the same rates conditions, and not involving the use of special stock.

---

(1) See the *Revue Générale*, March 1934.

Moreover, so that the clerical work may be centralised at the centre-stations, the receipt note given by the railway to the consignor, and stating the nature and weight of the parcel, the total carriage charge, and the time it will take, can be sent within 24 hours after the consignment has been handed over instead of immediately.

In the matter of *transit times*, the decree of the 19th January, 1934, has decreased from 125 to 200 km. per 24 hours the maximum transit time for ordinary goods traffic; on the other hand it allows the railways, when authorised by the Ministry of Public Works, to introduce in place of the express and slow goods services a common service for consignments of goods fulfilling certain conditions as regards nature, weight, or dimensions.

Moreover, provision is made whereby the legal transport times can be suspended when, owing to the failure of another method of transport, the amount of goods received for railway transport exceeds the capacity of the railway.

Finally, the decrees of the 30th December, 1933, and 19th January, 1934, authorise the railways, subject to the approval of the Administration, to replace rail services by *road services;* this substitution, in addition to the savings it may result in, is better for the public as the services run right into the towns and villages and there are more frequent stops.

The railway must be able to make use of the advantages offered by motor transport, to enable it to make its working more flexible and to give a better service more in keeping with the present-day demands of the public. The procedure for the approval of the rates for such services is, as we have said, the same as that that laid down by the decree of the 30th December, 1933, in respect of the railway rates. The periods for delivery are fixed by the Ministry of Public Works on suggestions from the Railways; any alterations which may be made therein in the case of services being actually operated come into force after 15 days notice, provided the Minister has raised no objection in the meantime.

The application of the clauses of these two decrees should make it possible for the railways to defend themselves on a fairer basis against other methods of transport, as the decrees grant them greater liberty in altering their tariffs, allow them to simplify their rates system, and ease in certain cases their obligation to carry at first notice all goods offered them.

In the first place, as the procedure for the approval of tariffs is more flexible, the railways can rapidly put into force new rates, as soon as such measures appear necessary, in order to combat a competitor, or seasonal rates, for short periods, required by the economic conditions of the moment; in a word, competition can be dealt with without delay. In the same way the adoption of minimum and maximum rates strengthens the position of the railways against motor competition, as the mere fact of showing possible competitors how little the railway can charge without any formalities being involved is often sufficient to stop such competition without actually lowering the rates.

Furthermore, it will be possible to simplify to some extent the tariffs thanks to the facility granted the railways of getting out the rates on other bases than the number of kilometres or the weight, such as by adopting area rates or sectional rates; likewise as the railway can abolish express and ordinary goods services in favour of a single class for certain consignments, the parcels rates can be simplified.

Finally, the suspension of the transit times in certain cases lessens the strict obligation incumbent on the railway to carry all goods offered, by not obliging them, for example when the navigation

on the Seine is interrupted, to carry from Rouen to Paris within 24 hours the considerable tonnage suddenly handed over to them.

These clauses might, however, be completed in various ways in order to allow the railways to act like their competitors in certain cases : in particular it would be a good thing to allow the railways to grant reduced rates to consignors who will undertake to send by railway all their traffic between given places for a given period, all consignors similarly placed and accepting the same conditions being, of course, allowed to take advantage of such reductions.

The principles laid down by the new decrees seem to be excellent; everything will depend upon the spirit in which they will be applied by the Railways and by the Government, which should not abuse its right of veto, while the former should avoid making too sudden changes in the rates, as this upsets business stability.

* * *

Sweden.

The information given below has been received by the courtesy of the Royal Administration of the Swedish State Railways.

This Administration has had recourse to various measures, such as the reduction of rates and the acceleration of transport

In the case of the organisation and improvement of door to door services, the Administration points out the following facts :

In certain places or populous districts, the State Railways have made agreements with certain contractors who deliver at fixed rates at the house, shop, or factory of the consignee all parcels arriving at the railway station and collect parcels from the consignor's premises for delivery to the raiway station, when a request for such services is received orally, by writing, or by telephone, by the station or the contractor.

In the case of one station (Astorp) which belongs to a private company but is connected to the State system, the two administrations have agreed to collect and deliver *free of charge* parcels carried or to be carried by rail.

A real door to door service, in which the rates include the cost of carrying the goods, from the consignor's premises to the station and from the destination station to the consignee, is not yet in existence. If the consignor wants his parcel taken to the station, the contractor charges for this service, and also acts as agent for the payment of the railway rates, if the goods are to be sent carriage paid. Likewise, on arrival, the charge for carriage from the station to the consignee is collected by the contractor to whom the consignee also pays the railway rates if the goods were sent carriage forward. The contractor subsequently hands over to the goods office of the station, the railway's share in the receipts.

In places where there is a goods cartage service, all parcels are delivered to the consignee within the limits of the locality. The user who wishes to collect or deliver his goods himself or by a third party must give notice of this in writing to the station.

When contracting out the cartage services, the cost of transport from the consignor to the station and the station to the consignee has been reduced as much as possible. In towns of some size the rates depend not only on the weight of the consignments, but also upon the zones into which the district is divided, according to the distance from the station the premises of the consignor or consignee are located. In some places the cartage charges are so low that the State Railways subsidise the contractor.

This subsidy is, in some cases, a fixed annual sum and, in others, is a percentage of the carriage rates; in other cases again it is based on the contractor being guaranteed a minimum value of receipts. Finally, as an experiment in order to induce the contractor to convass for traffic, in some cases the amount of the subsidy has been fixed as a percentage of the carriage charges in excess of a calculated annual figure of such charges. The subsidy system was introduced in 1933; consequently there has not been sufficient experience to show which method is the best. Nor can we state with certainty if the subsidies have brought to the State Railways traffic which otherwise would have been carried by other forms of transport.

The Railway Management has issued a pamphlet in order to bring to the public notice the towns near the State Railways with goods cartage services and the rates charged. This pamphlet will shortly be revised so as to simplify the cartage rates and make them more uniform for places of the same size.

Owing to the great length of the country, there are many villages and hamlets at some distance from each other which are not served by the railway. The nearest station is usually at the chief town in the district. For this reason, private motor services for passengers and goods have often been organised starting from the station and serving the villages through which they run. The State Railways have made with these road motor lines agreements for joint services so that goods arriving by rail are delivered to consignors living along the route served by the road motor service under the same conditions as those operating in more densely populated regions. Contracts dealing with the rates, etc., for such transport have been signed with these motor undertakings. But even so, there is no real door to door transport though the motor lorries deliver, for a fixed charge, all parcels the consignee is not able to collect himself. The road motor service collects the cartage fees from the consignee, as well as the railway charges when the goods have been sent carriage forward, which it pays in at the station. In the same way, the motor service will deal with the railway rates in the case of goods collected from the consignor and sent carriage paid by rail. As we have already said, particulars of these motor services working in conjunction with the railway and their rates will be included in the new edition of the pamphlet mentioned above. Similar contracts to those made with cartage undertakings have been entered into with private road motor lines. This system has been found practical and will gradually be extended to districts not linked up with the railway, where such services are needed and where there is a private motor service suitable for this purpose. The State Railways themselves only operate a small number of road motor services which start from their own stations.

In addition modifications have been made to the decree of 1930 on motor vehicles.

The decree of the 14th June, 1933, which came into force on the 1st January, 1934, contains some new clauses which we give below, as they affect the railway.

Line services.

Formerly the idea of a line service only covered traffic working to a regular timetable *over a given route.* There was nothing in such a definition to prevent regular traffic being maintained between two places by a road motor vehicle in district service, not authorised to run a line service, the only condition being that such a service should not cover the same route. The new wording of the paragraph in question makes it legally impossible to set up or continue

to run such a service. In practice, from now on, the idea of a line service will include not only traffic operating to a regular timetable over a given route, but also the traffic regularly transported between given places, even when carried over different routes.

Obligation to carry (§ 25, clause 2).

By the wording of the former § 25, clause 2, the obligation to carry within the limits of the traffic district in question only bound the concession holder operating town or district services in the case of *passenger traffic*. In future, the same obligation is laid down in the authorisation for *goods services* in town or district. In order to make sure that this clause will not become ineffective, a provision has also been made in § 28, clause 1, for maximum rates to be fixed by the competent Government Department.

Collecting goods on the outward journey and return loads
(§ 25, clauses 3, 4 and 5).

These questions are governed by the principle that town and country services handling goods traffic must meet the traffic requirements *within that particular traffic district*. But as motor vehicles used for services of this kind are allowed to carry goods from anywhere within this district to any other place, as well as to *pick up goods outside* the traffic district in order to transport them to some point within the traffic district, there does not seem to be anything contrary to the principle enunciated above, as in both these cases the traffic of their own district is dealt with.

Starting from this principle, the holder of a concession has no right to pick up goods from a place *outside* the traffic district in order to transport them to another place *outside* the same district. The holder of a concession for a district service in the Jönköping district, for example, can, on his journeys to Stockholm, pick up goods from any place *within the Jönköping district* (but not from towns unless he also holds the concession for the town services within that town); on the other hand, he cannot pick up goods at a place *outside* the district for transport to such a place. Against this, he might have the right, on the outward journey, to deliver at more than one place *outside* the traffic district goods collected *within his own* traffic district.

Outside the traffic district, goods can only be picked up from a *single place* during the same journey.

The restriction of the right to pick up goods is completed by a corresponding restriction concerning the return journey. The result is that a motor vehicle can only be utilised on the return journey in a district outside the traffic district in which the outward journey ended. To go back to the example quoted above, the driver of a lorry, after ending at Stockholm the journey begun in the Jönköping district, can only *accept in Stockholm* goods for his own traffic district (the Jönköping district). Consequently he has no right to accept goods for Södertälje, for example, nor for any other place outside the Jönköping district. But after he has got to the Jönköping district, there is nothing to prevent him accepting goods for transport to places further away.

Applications for licenses : how they are dealt with (§ 27).

Among the new arrangements of § 27, there is first of all the rule, in clause 1, that when an application is received for a license for a town or regional service, the competent authority must, by publication in a predetermined newspaper, give the transport firms affected by the service in question or other interested parties a chance to express their opinion on the application.

This is similar in principle to the procedure in the case of applications to start line services.

Article 2, clause 1, has been reworded : « The concession cannot be granted if the service in question is not necessary, because other transport undertakings already exist, or if, for other reasons, it is not judged useful. » In comparison with the old wording : « When considering applications for service licenses, the necessity and suitability of the service in question should be taken into consideration », the new text is more restrictive in nature, as closer examination into the request is wanted. In this connection the statement of the Head of the Department has to be mentioned : that, if need be, the enquiry into the need for the service should also look into the financial position of the applicant and the guarantees he can give that the service in question will be worked as required.

Working hours (§ 27, clause 7).

The old regulations on working hours stipulated that the working hours of a driver on the road should not normally exceed 13 hours, including rest periods, during 24 consecutive hours. The working hours during the period of 24 hours has been reduced to 12 hours in the present regulations.

The time the driver spends with his motor must be inclused in the working hours. The expression « with his motor » must not however be taken literally. Actually the working hours include the time the driver, without being actually on his vehicle, spends in looking after it, as well as the time spent in loading or unloading goods carried by the lorry, and in addition any rest period of less than 30 minutes or during which the driver must not leave his lorry.

The regulation that a driver must not drive for more than 6 hours on end without a rest period of at least 30 consecutive minutes, contained in the same clause, is very important both from the point of view of safety, and of competition.

In the case of long journeys, a spare driver is often carried, a bunk being fitted for him in many cases, especially in the large lorries, behind the driver's seat. But this system is no longer much used, as the time the spare driver spends in the lorry, whether asleep or awake, is counted as working time.

In this connection, the Head of the Department has expressed the opinion that journeys on which two men are needed to drive the lorry day and night in turn without other rest than that offered by the bunk in the vehicle should not be allowed; he adds that, moreover, there is really no need to work such traffic by motor lorry, since the railways and other vehicles are already available and give quite satisfactory service.

Way books (§ 27, clause 8).

In order to facilitate control by the competent police authorities, as to whether the regulations of the decree affecting motor vehicles are observed, it has been laid down that, for each motor vehicle used in urban or country traffic not solely engaged on passenger work, the concession holder must issue a special book (way book) in which the working times and journey made are entered.

If such entries are not kept up in the way book, or if the way book is not carried on each journey, the concession holder may be fined.

Regulations affecting hirers (§ 29*a*).

The regulations affecting the hiring out of motor vehicles, without driver, are quite new. They are especially important from the point of view of safety; they also serve as a protective

measure against competition, not only competition of road motor operators among themselves, but also competition between the motor and other methods of transport such as by railway and by sea.

* * *

Egypt.

The General Management of the Egyptian State Railways advised us that, up to the end of March, 1934, the methods adopted by this Administration to combat road competition have been as follows :

1. Reduction of fares in all classes.

2. Introduction of return tickets between all points at 10 % reduction on two single-journey tickets.

3. Introduction of special day return tickets at single fare and half on certain sections where motor competition is intense.

4. Improvement in train service by higher speeds and improved timings, and additional trains.

5. Opening of additional halts at suitable spots.

6. Creation of a road police service, partly at the expense of the Railway Administration, to see that the regulations in regard to operation of road motor cars are strictly observed.

7. The general question of additional taxes on motor cars, etc., is under consideration by the Government but no decision has yet been taken.

No steps have been taken to meet water competition or air competition as regards passenger traffic, as it is impossible to compete with the former owing to low rates charged, and the second is not serious.

In respect of water competition for goods traffic, a working agreement as regards respective spheres of action has been temporarily come to with certain organised transport firms.

* * *

British India.

As one of the means to compete with road motor traffic and regain some of the lost traffic, the concession of return tickets at a fare and a half for the double journey, available for the day of issue and the following day, was introduced as a trial measure over certain sections of the Bombay, Baroda and Central India Railway with effect from the 1st October, 1932, and the same is still current.

On one of the sections of this Railway, an additional train was put on to suit the convenience or passengers, but as it failed to attract traffic it had to be cancelled to avoid unremunerative operating expense.

[385. 587 (.493), 621. 138.5 (.493) & 625. 26 (.493)]

Reorganisation of the Malines main repair shops

(Belgian National Railway Company),

by A VERBEEMEN. Engineer, Malines Works.

Preliminary remarks.

The Malines main repair shops are the oldest on the system. All carriages and part of the locomotives are repaired there and, in addition, large quantities of spares are manufactured.

The different extensions made at various periods resulted in a heterogeneous collection of buildings, more or less out of date, covering an area of 40 hectares (98 acres); these shops were not suitable for modern working methods.

For administrative purposes the shops were divided into two separate divisions (carriages and locomotives), each with its own manager and executive services.

The Belgian National Company, in 1929, decided to reorganise its repair shops and the scheme provided for :

1. *Administrative reorganisation* with centralisation of the services;

2. *Technical reorganisation* of the shop methods and the adaptation of the buildings to suit.

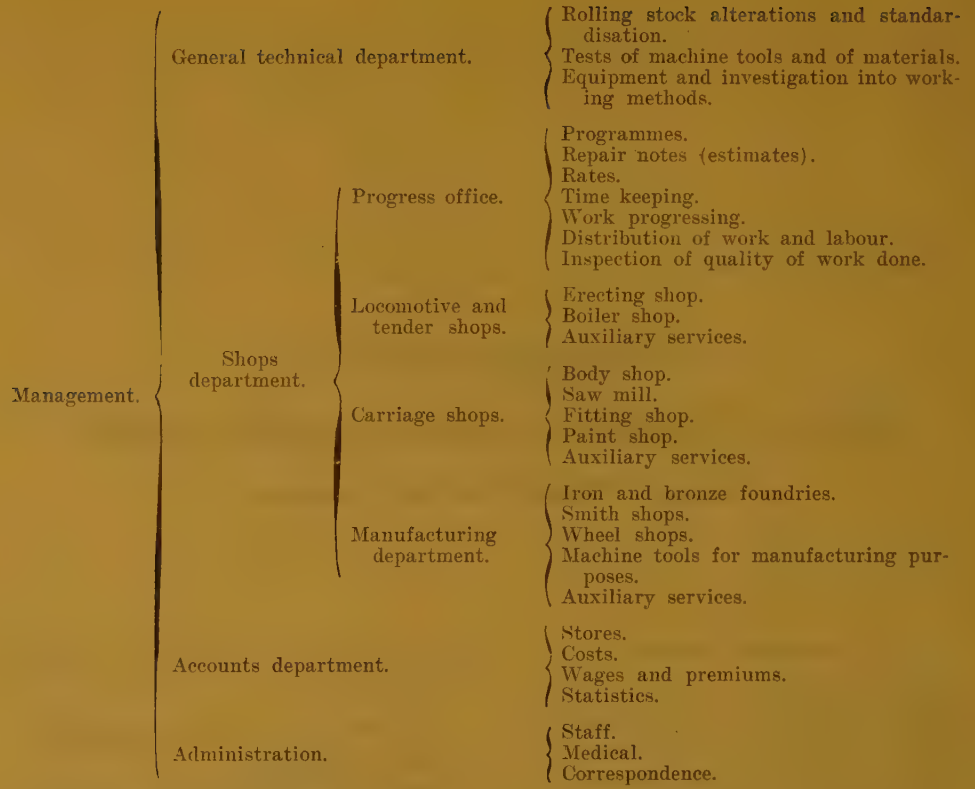
1. — The object of the **administrative reorganisation** was :

1. to combine the shops and services duplicated in the two divisions, carriages and locomotives, and in particular the smithies, turneries, tool makers shops, stores, administrative services, and the works transport;

2. to set up a planning department (progress office) responsible for investigating repair methods, and the scientific organisation of the work;

3. to remove the difficulties caused by the staff in the two divisions being under different wage conditions.

The general scheme of the reorganised services can be represented diagrammatically as follows :



2. — **Technical reorganisation.** — When the administrative reorganisation was completed (1929) the *locomotive repair shops* were as shown in plate 1 : the *erecting shop* with traverser and transverse engine pits, without cranes for lifting or handling materials, covered sites 13, 15 and 18; the layout of the *boiler shop* (sites 11 and 12) was on the same lines; the *turneries* were at 16 and 19 and the *smithies* at 14 and 17.

The work was carried out on the old lines. The engines to be repaired were given over to a repair gang; each gang had three locomotives in hand at different stages of repair. The leading hand listed the work to be done, ordered the materials and repair parts needed, and took all measurements required; he distributed the work to his men, decided the order in which the work was to be done, and recorded the times spent on it by his men. The maximum time allowed him for completing the repair was laid down and was the only control exercised over him. Specialisation of labour was little developed although some special gangs of fitters did motion repairs.

The defects of this system are well known; the time the repair took depended on the extent of the repair and the ability of the leading hand and his men. In spite of the efforts of the management the gangs in the erecting shop never

succeeded in getting a regular rhythm of work into and out of the shop; the special gangs and auxiliary sections being supplied with work irregularly could not satisfactorily meet so essentially variable a demand.

The work of the fitters and erectors was frequently interrupted and the progress of the repairs was affected by all sorts of unforeseen happenings.

Under such conditions the output of the men could but be poor.

A locomotive general repair took about 60 working days and absorbed some 6 500 man-hours.

The position in the *carriage repair shops* was the same. They consisted essentially of a stripping shed (27), a repair shop (31), and a paint shop (32). The repair work was in the hands of non-specialised gangs and the sole attempted organisation was a progress schedule, which moreover was seldom followed.

Bogie stock was repaired in a separate shop (28).

Such methods did not come up to modern ideas of a repair shop, and a complete reform was needed. The technical reorganisation immediately came up against material difficulties :

1. The existing buildings had to be used in the best possible way;

2. The alterations must be carried out without interfering with production.

The suggested new layout provided for the :

a) Construction of a shop (38) for stripping the carriages in order to liberate buildings 27 and 28;

b) Construction of a boiler shop (29) against building 28;

c) Construction of an erecting shop (26) alongside shed 27;

d) Installation of up to date heating equipment, compressed air, and acetylene plants.

The locomotive repairs were thus concentrated in shops 26 to 30, and carriage repairs in 31 to 38;

e) Conversion of the old shops into stores.

The construction of the new shop suggested under *a*), was subsequently given up, as by applying the belt method of working to these carriage repairs it was found possible both to strip and repair the coaches in building 31.

This scheme took two years' work to complete (1931 and 1932); the repairs to carriages and locomotives were transferred to the new shops on January 1st, 1933, without there having been the slightest delay in turning out the vehicles.

* * *

PART ONE.

GENERAL ORGANISATION OF THE WORK.

A main repair shop responsible for heavy repairs to large numbers of locomotives and carriages of different types has to deal with great differences in kind and extent as regards the work to be done.

Under these conditions a satisfactory output from the staff can only be expected if an improved organisation which will co-ordinate the whole of the work in an orderly and methodical way is introduced.

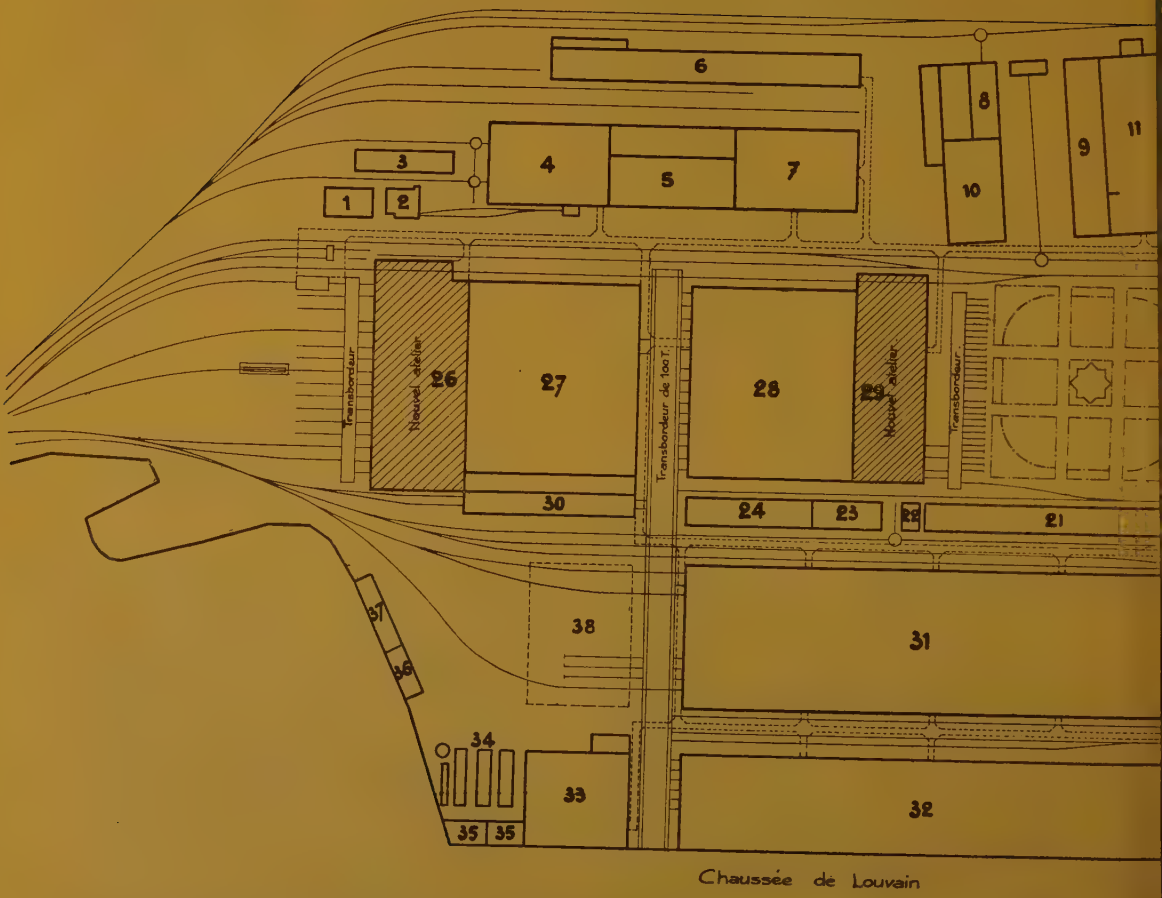
The principal factors in such an organisation are :

a) The preparation, distribution, and control of the work progress by the *Progress Office;*

b) The measurement of the time taken by the various operations;

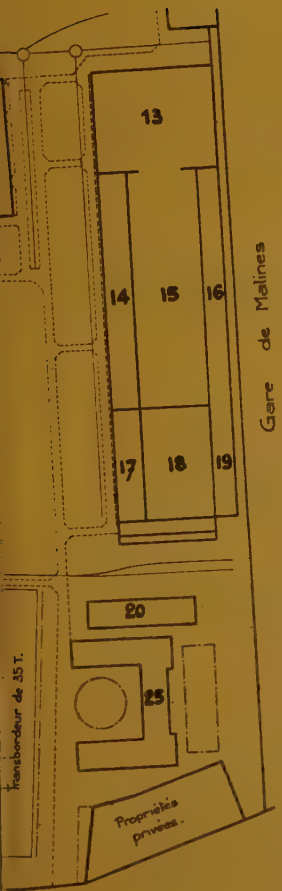
Belgian National Railways Company

The Malines Main Shops



Note : Transbordeur = Traverser. — Nouvel atelier = New shop. — Gare de Malines = Malines station. — Propriétés pri

PLATE I.



EXPLANATION

1	Timber shed.	
2	Timber drying shed.	
3	Shed for sawn timber.	
4	Saw mill.	
5	Electric power house.	Progress section.
6	Smithies.	
7	Machine tools and gauges (manufacturing).	
8 - 9	Foundries.	
10	Pattern room.	
11	General service. Distribution of machine tools.	
12	Despatching services.	Former locomotive shop.
13to18	Stores.	
19	Wheel lathes.	
20	Toolmakers.	
21	Offices.	
22	Acetylene plant.	Combined services (locomotives and carriages).
23	Air compressors.	
24	Central heating plant.	
25	New offices (under construction).	
26	Locomotive erecting shop.	
27	Secondary erecting belt working.	
28	Tenders and secondary boiler work belt.	New locomotive shops.
29	Boiler shop.	
30	Painting and trimming.	
31	Carriage repair shop.	
32	Carriage painting shop.	
33	Upholsterers.	
34	Sheet drying.	Carriage shops.
35	Preparation of colours.	
36	Laundry plant.	
37	Bathrooms.	

c) The systematic control of the quality of the work done.

The organisation is based upon the following essential principles :

1. Repairs to complete vehicles, groups of parts, units and details forming them, should be carried out according to *standard schedules*, and within the *time limits* fixed beforehand; the same applies to the manufacture of spare parts;

2. All the repairs required should be laid down very exactly by inspectors and should be entered on *inspection notes* describing in chronological order, as regards the succession of operations, the whole of the work to be done; these inspection notes, completed by adding the operation times, form the *estimates* of the repairs required;

3. The *progress office* is solely and entirely responsible for issuing orders; no workman can carry out any work without an *order* (job card) from the progress office, based on the information on the inspection notes. This order fixes the work to be done, the time required to do it, and the date it must be completed; the time the job is begun and ended is recorded by *mechanical time recorders;*

4. These job cards are distributed by the progress office itself, so that it can see each job completed in the time allowed by the standard schedules, according to the *planning schedules* which exactly detail beforehand how each man is to be employed, with full particulars for completing each job;

5. The progress office is responsible for co-ordinating the whole of the work at all times, and for seeing that the labour available in the shop is suitably distributed; full use should be made of the available labour and each section of the shop should be in a position to carry out the work given it;

6. The method of doing the work and the time needed to finish each job are to be laid down; this falls to the *operations timing* services;

7. For the operations to follow on with regularity the work has to be carried out properly and any mistakes corrected immediately; the inspection of the work for quality should be complete and precise.

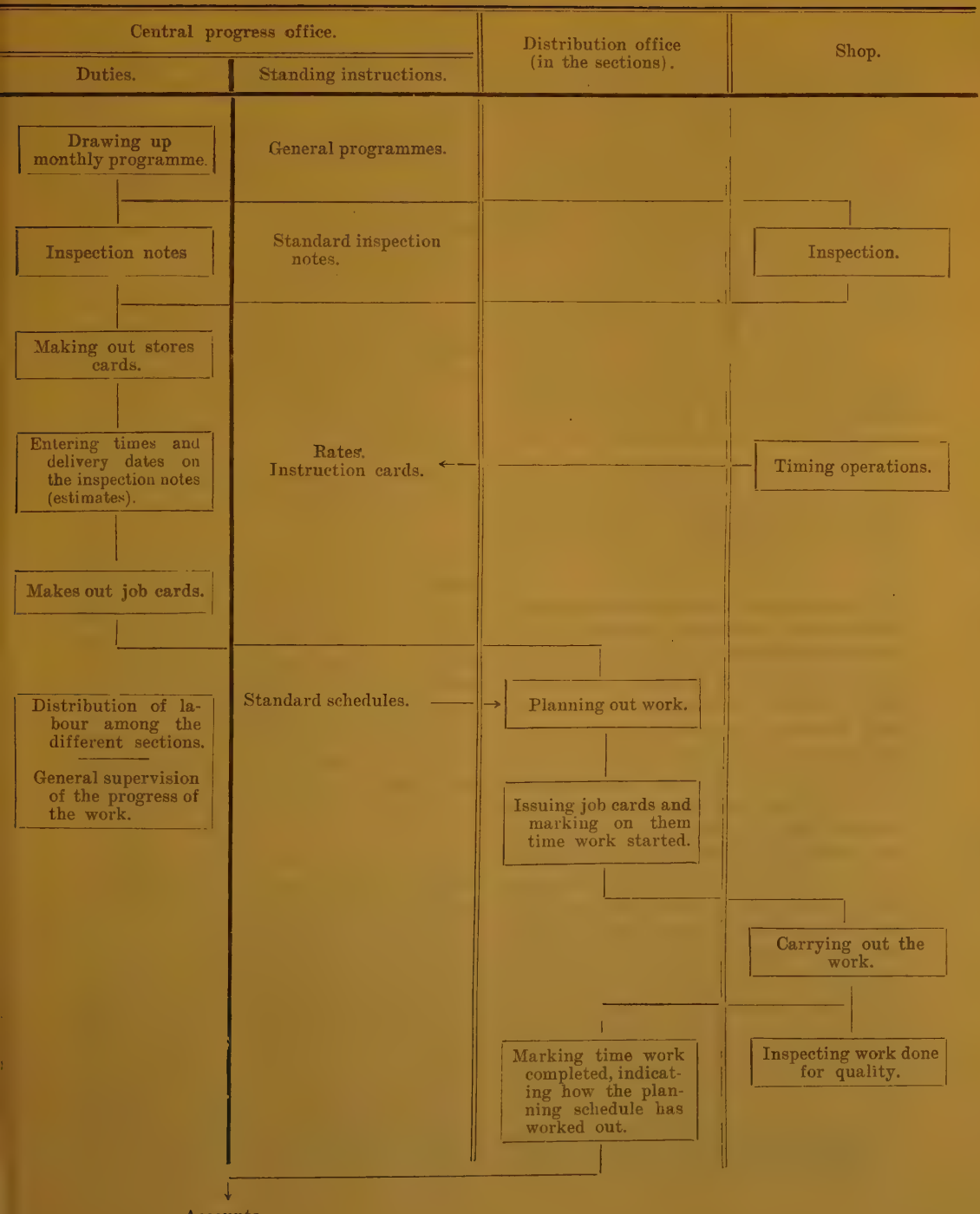
The organisation includes a *central progress office*, the main functions of which include the *preparation of the work* (investigation of schedules, drawing up inspection forms, writing out job and stores cards); the *distribution of labour* and the *general control of the progress of the work;* and in each section a *distribution office* which is responsible for looking after the *planning schedules, issuing job cards and recording the times on them*, and for seeing that the jobs being done by the section *progress regularly*.

The functions of the progress office and its connection with the shops are as shown on the following page.

I. — Preliminary work (central progress office).

a) *General programmes.*

Another great modification in the working method has been to apply, to the greatest possible extent, to the repair work, the principles of the *moving belt system.* In the present case the belts move forward intermittently; each forward movement takes place at regular intervals and brings the vehicle or part in line with the next specialised stand. The advantages of this method are too well


Central progress office.
Duties.
Standing instructions.
Distribution office (in the sections).
Shop.
Drawing up monthly programme.
General programmes.
Inspection notes
Standard inspection notes.
Inspection.
Making out stores cards.
Entering times and delivery dates on the inspection notes (estimates).
Rates.
Instruction cards.
Timing operations.
Makes out job cards.
Distribution of labour among the different sections.
General supervision of the progress of the work.
Standard schedules.
Planning out work.
Issuing job cards and marking on them time work started.
Carrying out the work.
Marking time work completed, indicating how the planning schedule has worked out.
Inspecting work done for quality.
Accounts.

known to spend any time dealing with them; we will consider later on how it has been applied to the progressive repair of locomotives and carriages.

From the point of view of drawing up the *general programmes*, the application of these principles for a given vehicle or part of any type means *uniform periods of progress and completion.*

The programmes should ensure that all labour is fully used all the time in the whole of the shops.

In addition, as the men of the Belgian National Railways Company are permanently employed, no great variations in the establishment at short notice can be considered.

The general problem therefore appears to be the following one : to complete with a fixed staff, in uniform periods, work of much varying importance.

The solution : to *equilibrate the general programme* so as to make the average of the work as constant as possible and to have available a sufficient number of men to absorb any variations which may still occur.

In order to obtain this result in the carriage side, the general programme has been drawn up so that steel carriages and wood carriages are sent in in due proportion; bogie carriages, and the four and six-wheeled carriages are also mixed up in the same way, the 3rd-class with the 1st and 2nd-class, and seriously damaged coaches with those requiring less extensive repairs.

Coaches requiring heavy repairs are previously examined in the sidings, and the progress office prepares monthly from the data collected in this way the programme of the repairs to be taken in hand.

In the case of the locomotive shops, the same procedure is followed, the tonnage, number of pairs of wheels, the number of cylinders, etc., being taken into account.

The way these programmes are drawn up is of capital importance and of the greatest help as regards regular working of the various departments. A badly balanced programme inevitably leads to delays and involves serious redistribution of the available labour.

b) *Documents in connection with the work. Preparation of inspection and repair notes.*

In repairing vehicles the work done can be divided up into three categories :

1. Work to be done regularly;

2. Work expected to be necessary more or less regularly;

3. Casual jobs.

The progress office prepares for each part of the vehicle a list of known defects, with the work required to make them good. Then, by grouping these operations, it draws up for each section of the shop a *chronological* list of *all possible and allowable* operations.

This list becomes the inspection note, filled in after carrying out the inspection, the times allowed being entered on it; the form then becomes the *estimate* (repair note).

As an example we give (Plate II) an inspection note covering the repair of connecting rods and coupling rods of locomotives of various types.

It should be noted that :

1. Attempts have been made to reduce as far as possible the number of different inspection forms by making them suitable for use with several types of locomotives or carriages. For example, one single inspection form is applicable to all boilers repaired at the Malines main works;

2. Each operation is numbered so that it is readily defined;

3. The inspection note gives the machine tool, the man or men who have to carry out the work;

4. In principle each detail job should be covered by a distinct card. However, in order to avoid too great multiplication of orders and loss of time in checking the cards, operations which can be done by one man or gang have been grouped under the letters A_1, A_2, A_3... between two horizontal strokes, each group corresponding to one job card.

In this way cards taking one to eight hours to complete are obtained; it is important that this period should not be too long so that the progress made can be controlled at all times.

Drawing up rates lists. — When the reorganisation was taken in hand, quite complete rates lists giving the times required for repair operations were in existence in the various sections of the shops. They were drawn up by estimation and subsequently corrected by the results obtained in practice; however, their accuracy was quite questionable. In addition, as regards erection and fitting, a price was most frequently given for the work as a whole.

The new organisation required that the methods and timings be obtained from methodical time records of all the separate items on the inspection note.

In order to save time this heavy work was divided up between the three main locomotive repair shops of the Belgian National Railways Company, the times obtained in one being applied to the other two. Care was also taken to perfect the working methods in use, while at the same time correcting any obvious defects, such as the misuse of a machine tool, use of unsuitable tools, defective erection, etc.

The work of taking timings is very well advanced and will be completed by the end of 1934; it has given particularly interesting results from an output point of view. The method used can be followed quite clearly by examining the timings cards used (Specimen A, pages 799 to 802). The time keepers use the Michelin type of board with three chronometers.

The timings recorded are entered on the instruction cards (Specimen B, page 803) which lay down definitely the details of the method to be adopted.

The whole of the timings relating to a section of a shop form the *rate table* (plate III). This document is on the same lines as the inspection notes; it shows, in the same order and under the same headings, the whole of the operations which may have to be carried out on the different types of vehicles.

Preparation of standard progress schedules. — Repair work by its nature varies considerably even for vehicles of the same type; many operations only recur at long intervals. Each operation, however, ought to be taken in hand at a definite time, both to coordinate the work carried out in the different sections and in order to avoid any delay in distributing the work.

In order to obtain this result all the different repairs which can arise have been investigated. A comparative study of them has resulted in standard schedules which cover all possible cases, fixing in each case the date of completion.

For example, Plate IV shows the standard schedule for dealing with boilers; it shows vertically the whole of the different possible operations, while horizontally the rectangles show the *extreme* time limits within which a given operation ought to be carried out.

The *number of standard schedules* required has been reduced to a minimum.

PLATE II.

LOCOMOTIVE AND ROLLING STOCK DEPART^{T}. SHEET NUMBER 1.

Detailed inspection and repair note

Malines Repair Shop.

Order number .....

Charge .....

a) Section : **connecting rods secondary belt.**

b) Locomotives : **T. 64 - 81 - 90.**

c) Date vehicle taken in hand .....

d) Date order received .....

Rate No.	WORK.	No. of parts.	Preparatory time.	Time to do work: Allowed per unit.	Time to do work: Total allowed.	Time to do work: Time taken.	Job card number.	Date work done: laid down.	Date work done: actual.
1 / VI	**Preparation of work for inspection.**								
a	connecting rod								
b	intermediate coupling rod T.81-90								
c	leading coupling rod T.64								
d	coupling rod. 4th pair of wheels T.90								
e	trailing coupling rod T.64-81-90								
f	leading coupling rod T.81-90								
2 / AI	**Welding.**								
a	building up side faces of rod ends. . . . . dcm.								
b	building up rod ends, 3 mm. . . . . dcm^2								
c	building up rod ends more than 3 mm. . . cm^3								
d	building up body of rod . . . . . dcm^2								
e	buiding up knuckle pin holes :								
	Ø 80 to 85 mm., 3 mm. added. . . . . cm.								
	Ø 86 to 90 mm. » . . . . . cm.								
	Ø 91 to 95 mm. » . . . . . cm.								
	Ø 96 to 100 mm. » . . . . . cm.								
	Ø 101 to 105 mm. » . . . . . cm.								
	Ø 106 to 110 mm. » . . . . . cm.								
f	building up taper of the knuckle pin :								
	Ø 80 to 85 mm., 3 mm. added. . . . . cm.								
	Ø 86 to 90 mm. » . . . . . cm.								
	Ø 91 to 95 mm. » . . . . . cm.								
	Ø 96 to 100 mm. » . . . . . cm.								
	Ø 101 to 105 mm. » . . . . . cm.								
	Ø 106 to 110 mm. » . . . . . cm.								
g	building up wedges and distance pieces; 3 mm. added . . . . . dcm^2								
h	building up holes Ø 25 to 30 mm. . . . . cm.								
3 / SI	**Smith work and heat treatment.**								
a	adjusting length : lengthening	See detailed repair note for smith shop.							
b	adjusting length : shorthening								
c	straighthening rod								
d	heat-treating rod								

PLATE II.

LOCOMOTIVE AND ROLLING STOCK DEPARTT. SHEET NUMBER 2.

Detailed inspection and repair note.

Rate No.	WORK.	No. of parts.	Preparatory time.	Time to do work: Allowed per unit.	Time to do work: Total allowed.	Time to do work: Time taken.	Job card number.	Date work done: laid down.	Date work done: actual.
4/C1	**Inspection of smith shop work.**								
a	connecting rod								
b	intermediate coupling rod T.81-90								
c	leading coupling rod T.64								
d	coupling rod, 4th pair of wheels T.90								
e	trailing coupling rod T.64-81-90								
f	leading coupling rod T.81-90								
5/A2	**Grinding sides of rod ends.**								
a	connecting rod face.								
b	intermediate coupling rod T.81-90. face.								
c	leading coupling rod T.64. face.								
d	coupling rod, 4th pair of wheels T.90 face.								
e	trailing coupling rod T.64-81-90 face.								
f	leading coupling rod T.81-90. face.								
g	built up side of body. dcm.								
h	built up face of knuckle face.								
6/A3	**Milling rod ends.**								
	Connecting rods : T.64-81-90.								
a	large end								
b	small end								
	Coupling rods :								
c	leading T.64 : large end.								
d	leading T.64 : small end.								
e	intermediate T. 81-90 : large end								
f	intermediate T.81-90 : small end.								
g	4th pair of wheels, T. 90 : small end								
h	leading T.81-90 : small end.								
i	trailing T.64-81-90 : small end								
	Connecting and coupling rods : T.64-81-90.								
j	built up body of the rod dcm.								
k	knuckle : built up inner face face.								
l	removing oil well cover								
m	adjusting height of oil well cover								

PLATE III.

LOCOMOTIVE AND ROLLING STOCK DEPARTT. — SHEET NUMBER 1.

Detailed rates.

Malines Repair Shop.

Connecting rod secondary belt.
T. 64 - 81 - 90.

Rate No.	OPERATIONS.	TIME ALLOWED PER UNIT.							
		T. 64.		T. 81.		T. 90.			
		Prepa-ration.	Actual work.	Prepa-ration.	Actual work.	Prepa-ration.	Actual work.	Prepa-ration.	Actual work.
1 / V1	**Preparation of work for inspection.**								
a	connecting rod	0.06	0.24	0.06	0.24	0.06	0.24		
b	intermediate coupling rod T.81-90		—		0.28		0.28		
c	leading coupling rod T.64		0.25		—		—		
d	coupling rod, 4th pair of wheels T.90		—		—		0.14		
e	trailing coupling rod T.64-81-90		0.14		0.14		0.14		
f	leading coupling rod T.81-90		—		0.14		0.14		
2 / A1	**Welding.**								
a	building up side faces of rod ends. dcm.		0.073		0.073		0.073		
b	building up rod ends, 3 mm. dcm²		0.30		0.30		0.30		
c	building up rod ends more than 3 mm. cm³		0.012		0.012		0.012		
d	building up body of rod dcm²		0.30		0.30		0.30		
e	building up knuckle pin holes :								
	Ø 80 to 85 mm., 3 mm. added. cm.		0.126		0.126		0.126		
	Ø 86 to 90 mm. » cm.		0.136		0.136		0.136		
	Ø 91 to 95 mm. » cm.		0.146		0.146		0.146		
	Ø 96 to 100 mm. » cm.		0.156		0.156		0.156		
	Ø 101 to 105 mm. » cm.		0.166		0.166		0.166		
	Ø 106 to 110 mm. » cm.		0.176		0 176		0.176		
f	building up taper of the knuckle pin :								
	Ø 80 to 85 mm., 3 mm. added. cm.		0 136		0.136		0.136		
	Ø 86 to 90 mm. » cm.		0.146		0.146		0.146		
	Ø 91 to 95 mm. » cm.		0.156		0.156		0.156		
	Ø 96 to 100 mm. » cm.		0.166		0.166		0.166		
	Ø 101 to 105 mm. » cm.		0.176		0.176		0.176		
	Ø 106 to 110 mm. » cm.		0.186		0.186		0.186		
g	building up wedges and distance pieces; 3 mm. added dcm²		0.30		0.30		0.30		
h	building up holes Ø 25 to 30 mm. cm		0.08		0.08		0.08		
3 / S1	**Smith work and heat treatment.**								
a	adjusting length : lengthening								
b	adjusting length : shorthening								
c	straighthening rod				See smith shop.				
d	heat-treating rod								

PLATE III.

LOCOMOTIVE AND ROLLING STOCK DEPARTT. SHEET NUMBER 2.

Detailed rates.

Rate No.	OPERATIONS.	TIME ALLOWED PER UNIT.							
		T. 64.		T. 81.		T. 90.			
4 / C1	**Inspection of smith shop work.**	Preparation.	Actual work.	Preparation.	Actual work.	Preparation.	Actual work.	Preparation.	Actual work.
a	connecting rod	0.06	0.20	0 06	0.20	0.06	0.20		
b	intermediate coupling rod T.81-90		—		0.24		0.24		
c	leading coupling rod T.64		0.21		—		—		
d	coupling rod, 4th pair of wheels T.90		—		—		0.13		
e	trailing coupling rod T.64-81-90		0.13		0.13		0.13		
f	leading coupling rod T.81-90		—		0.13		0.13		
5 / A2	**Grinding sides of rod ends.**								
a	connecting rod face.	0.09	0.32	0.09	0.32	0.09	0.32		
b	intermediate coupling rod T.81-90. face.		—		0.19		0.19		
c	leading coupling rod T.64. face.		0.21		—		—		
d	coupling rod, 4th pair of wheels T.90 face.		—		—		0.18		
e	trailing coupling rod T.64-81-90 face.		0.18		0.18		0.18		
f	leading coupling rod T.81-90. face.		—		0.18		0.18		
g	built up side of body. dcm.		0.0175		0.0175		0.0175		
h	built up face of knuckle face.		0.191		0.191		0.191		
6 / A3	**Milling rod ends.**								
	Connecting rods : T.64-81-90.								
a	large end	0.122	0.414	0.122	0.418	0.122	0.418		
b	small end	0.127	0 367	0.127	0.367	0.127	0.367		
	Coupling rods :								
c	leading T.64 : large end.	0.122	0.429		—		—		
d	leading T.64 : small end.	0.122	0.373		—		—		
e	intermediate T. 81-90 : large end		—	0.122	0 429	0.122	0.429		
f	intermediate T.81-90 : small end.		—	0 122	0.373	0.122	0.373		
g	4th pair of wheels, T. 90 : small end		—		—	0.122	0 373		
h	leading T.81-90 : small end.		—	0.122	0.373	0.122	0.373		
i	trailing T.64-81-90 : small end	0 122	0.373	0.122	0.373	0.122	0.373		
	Connecting and coupling rods : T.64-81-90.								
j	built up body of the rod dcm.	0.02	0.143	0.02	0.143	0.02	0.143		
k	knuckle : built up inner face face.	0.09	0.13	0.09	0.13	0.09	0.13		
l	removing oil well cover	0.10	0.22	0.10	0.22	0.10	0.22		
m	adjusting height of oil well cover	0.15	0.09	0.15	0.09	0.15	0.09		

Thus, in the boiler shop all repairs are carried out according to one schedule, which, however, includes two variants in the erecting shop, namely :

a) repair including replacement of a complete firebox;

b) all other repairs.

It has also been found possible to include in one schedule the whole of the repairs to carriages of all types.

In addition, in preparing the standard schedules the fullest use has been made of the *moving belt principle;* the intermediate times are equal to the unit time adopted or multiples thereof.

Exceptionally heavy repairs which mean stopping all the vehicles a very long time have not been taken into account. Taking the boiler shop, for example, the standard schedule makes no provision for the replacing of a throat plate; when this has to be done a double shift is worked so as to keep within the time allowed. It should be noted that the *standard schedule,* thus composed, can be applied, without working double shifts, in more than 95 % of the cases.

As regards the *total repair times* laid down in the schedules, they have been gradually reduced by carefully looking into the repair work, and by the experience acquired in carrying it out.

As an example, in the section dealing with heavy repairs to locomotives, the total time out of traffic has been reduced from 45 to 20 working days, in less than two years' time, without using spare boilers nor double shifts.

* * *

The inspection note, scale of rates, and instruction card are the three documents on which the preparatory data are based. By means of this information, the time required for each job, the way to deal with it, and the exact moment it will be done are known.

c) *Preparation of the work.*

Inspection of parts (repair work). — When the different parts of the vehicle are stripped down and cleaned, they are inspected in order to decide whether they are good for further service, should be repaired, or be replaced.

The inspector looks after this work. He decides in detail the work to be done in the shop.

Formerly the inspectors, selected from the best workmen, based the repairs required on their practical knowledge. The system had many drawbacks, largely because the inspector's decision was more or less empirical, as the work was not done methodically, and no definite instructions were available.

To make good these defects the following steps were taken :

1. Any responsibility as regards carrying out the work has been taken from the inspector. He is thereby less liable to influences likely to affect his judgment. All the inspectors come under the central progress office;

2. A limited number of allowable operations has been specified. Now that the inspection notes are available, the examiner need not hesitate as to the method to be followed; every case has been provided for;

3. The maximum allowable wear has been laid down in all cases. The inspector can thereby decide without hesitation whether a part is good or requires repairs and which are the repairs needed, or again if it must be replaced.

We have in this way almost completely

SPECIMEN A (*1st page*).

Timings card.

Work .....

Operation. .....

Drawing number .....

Material ..... Pattern No. .....

Shop .....

Number of men .....

Number and description of the machine tool .....

Sequence of timings.

No. of timings								
Dates								
Time started								
Time ended								

Sketch.

Single operation. number.	Record number.	INTERRUPTION.	Time.	Single operation number.	Record number.	INTERRUPTION.	Time.

Single operation number.	Particulars of the surface machined.	Single operations.	Times mea							
			1	2	3	4	5	6	7	8
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										

SPECIMEN A (2nd & 3rd pages).

operation number.	Record number.	INTERRUPTION.	Time.	Single operation number.	Record number.	INTERRUPTION.	Time.

ed. 10	11	12	13	14	15	Total time of the record.	Average time.	Maximum time.	Minimum time.	Remarks.	Order No.
											1
											2
											3
											4
											5
											6
											7
											8
											9
											10
											11
											12
											13
											14
TOTAL. . .											

SPECIMEN A (4th page).

Times of interruptions during the series of observations recorded.

Particulars of the interruptions.	Various times recorded.						Total.	Standard unit time.	Standard frequency.	Total standard time.
Totals. . .										
% of the whole of the unit operation times.										

SUMMARY.

Preparation time .....

15 % for time lost .....

Preparation time allowed t_p .....

Operation times .....

10 % for time lost .....

Operation times allowed t_o .....

	Per man.	To the gang.
Time allowed for 1 piece		
Time allowed for n pieces $= t_p + n.t_o$		

PROPOSED IMPROVEMENTS.

.....

.....

.....

.....

.....

.....

Signature of time recorder,

Approved by the Engineer of the Section,

Approved by the Workshops Manager,

SPECIMEN B.

Instructions card No. .....

Work .....

Operation .....

Drawing number ..... Pattern number ..... Material .....

Shop ..... Number of men ..... Rate .....

Machine tool, number and description .....

Description and number of tools, jigs, and other equipment .....

Number of the single operation.	TOOL EQUIPMENT.	MACHINING.			SINGLE OPERATIONS.	TIME	
		Speed per minute.	Feed in mm.	Cut in mm.		Preparation.	Operation.

REMARKS.			
	Totals in minutes and hundreths . . .	.....	.....
	Increment, minutes and hundreths, for time lost		.....
	Time allowed per part, in hours and hundreths	t_p	t_o
Entered by ..... on the			
Checked by ..... on the	Time allocated for parts . . . . $= t_p + n.t_o.$	.....	.....

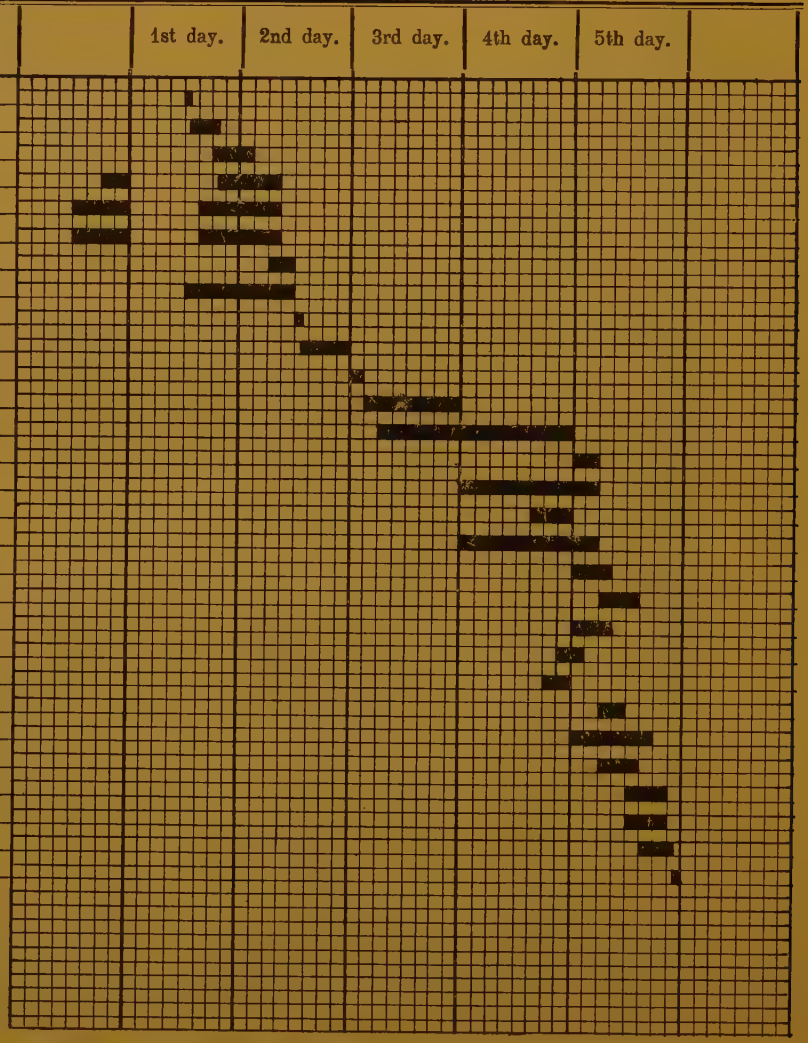
MALINES MAIN SHOPS.

Boiler work.

Standard schedule.

Stripping.

No.	OPERATION.	Index.
1	Shop boiler and wash out (with water)	A 1
2	Strip elements and header.	A 2
3	Take down steam pipe	A 3
4	Cut out and remove flue tubes	A 4
5	Cut out and remove smoke tubes	A 5
5	Withdraw brass tubes	A 7
6	Remove barrel	A 8
7	Drill firebox roof stays.	B 1
8	Take boiler to sand blast stand	B 2
9	Clean boiler by sand jet	B 4
10	Inspection.	
11	Drill firebox stay heads	B 3
12	Cut off rivet heads	C 1
12	Cut away boiler plates	C 3
13	Remove stays	C 2
14	Remove back tube plate, bottom of box	C 4
14	Cut out and remove firebox	C 5
15	Offer up new plates	
15	Remove smoke box	C 9
15	Bevel off copper side plates	C 10
15	Cut out remaining stays	C 16
16	Remove lower part firebox casing	C 8
17	Remove barrel plates	C 7
17	Remove roof stays	C 6
18	Remove throat plate.	C 11
19	Remove firebox back plate.	C 12
19	Separate barrel from firebox	C 13
20	Clean the boiler	C 14
21	Remove the boiler	C 17



SPECIMEN C.

LOCOMOTIVE AND ROLLING STOCK DEPARTMENT

Job card for individual work N.....

Shop : ..... Workman's No. : ..... Charge number : .....

Division : ..... Workman's name : ..... Order number : .....

Schedule date : .....

Rate number : .....

Allocation .....

Description of parts .....

Quantity : ..... Operation : .....

TIMES — ACTUAL	Time spent.

Place or machine tool	Next job	Next machine tool

Initials of checker.	Time taken.

eliminated the personal factor. The inspector examines the part, enters on the inspection note the work to be done, according to the instructions on limits of wear and repair methods, without being influenced by machining difficulties.

Inspection of materials. — When a « repair work » inspector decides a piece must be renewed, an employee conversant with the stores position decides if the part has to be made or if it can be drawn from stores. He prepares a statement of the materials required.

In most cases the « repair work » inspector carries out the « stores » inspection duties as well.

Preparation of job cards. — On receipt of the « inspection note », the main office staff look up in the scales the allowances for the work to be done. The dates by which the work is to be completed are obtained from the schedules. The inspection note is completed by entering in on it this information, after which job cards are filled in for the various groups of operations. The number of the job card is written on the inspection note.

We have already remarked that the individual operations are grouped beforehand so that each job card is for a reasonable amount of work.

The job card is said to be « individual »

SPECIMEN D (*front*).

Belgian National Railways Company

Locomotive and rolling stock department

Shop : .....

CARD No. 29642

Job card for work done by gangs.

Division : ..... Gang : .....

Order number : ..... No. of charge : .....

HOURS TAKEN.			INTERRUPTIONS.		TIMES — ACTUAL	Time spent
Number and name of man.						
.....	.....					
Carried fo ward	Month	TOTAL				
.....	.....	.....				
Number and name of man.						
.....	.....					
Carried forward	Month	TOTAL				
.....	.....	.....				
Number and name of man.						
.....	.....					
Carried forward	Month	TOTAL				
.....	.....	.....				
Number and name of man.						
.....	.....					
Carried forward	Month	TOTAL				
.....	.....	.....				

when the work is to be done by one man *(Specimen C)*.

The « gang » card is used when the work is to be done by a number of workmen *(Specimen D)*.

Care has been taken, however, to make the largest possible number of jobs « individual », as the progress of the work and the output is much more easily controlled. At the present time the use of two men on one job is exceptional.

The job cards are then sent to the different sections. At the present moment they give the following information :

1) order number,
2) shop,

SPECIMEN D (*back*).

HOURS TAKEN.	INTERRUPTIONS.	TIMES — ACTUAL.	Time spent.
Number and name of man.			
Carried forw. | Month. | TOTAL.			
Number and name of man.			
Carried forw. | Month. | TOTAL.			

Distribution of working hours over the shop sections

Card N° .....

Order number : ..... Charge number : .....

Shop section :	Shop section : .....
Number of hours :	Number of hours : .....
Shop section :	Shop section : .....
Number of hours :	Number of hours : .....

TOTAL	Allocation. Rate number	Number of parts.	Unit allocation.	Total allocation.

3) particulars of the work,
4) rate number,
5) allocation,
6) date the work is to be finished.

Filling in the stores cards (Specimen E). — These cards are filled in at the central office according to « materials » estimates and are used to order parts or raw materials from stores.

They contain the following information:

1) date of booked delivery required,
2) particulars of the order,

Belgian National Railways Company.

LOCOMOTIVE AND ROLLING STOCK DEPARTMENT.

N°

SHOP : .....

Stores card. — Materials. Accounts.

DATE : .....

I. STORES.	II. COST PRICE.
a) Description of object :	Order number : .....
.....	
.....	
b) Vocabulary number :	Charge : .....
c) Chapter number :	
d) Stores accounts number :	

QUANTITY.		VALUE.	
Asked for.	Delivered.	Unit.	Total.
Initialed at progress office :		Storekeeper's initials :	

Belgian National Railways Company.

LOCOMOTIVE AND ROLLING STOCK DEPARTMENT.

N°

SHOP : .....

Deduction card. — Materials. Stores.

DATE : .....

I. STORES.	II. COST PRICE
a) Description of object :	Order number : .....
.....	
.....	
b) Vocabulary number :	Charge : .....
c) Chapter number :	
d) Stores accounts number :	

QUANTITY.		VALUE.	
Returned to stores.	Number in store.	Unit.	Total.
Initials of storekeeper for receipt.			

3) description of the part,
4) part number,
5) quantity ordered.

d) *Manufacturing orders.*

In addition to the repair shops, there are at Malines sections for making new parts, and in particular an iron foundry, a brass foundry, a smith shop, a machine tool shop, and a fitting shop.

These sections manufacture parts for keeping up the stores' stock; such manufacturing is usually done on mass production lines.

The storekeeper has a stock card for every detail in the stores; on this card are entered the receipts and issues.

This card shows the « maximum » and « minimum » stocks based on the normal consumption.

When the stores' stock falls to the minimum allowed for the estimated consumption, the stores issue a stores stock order.

Orders can also be issued by the outside departments, and also by the « materials » inspectors when the part wanted is not in store.

All these orders are sent to the central progress office which decides where the work is to be done, collects the drawings, and fixes the time within which each section must complete the work.

The central office then decides which machine tools are to be used, allocates the time, and fixes the dates for completion of each operation; it prepares an estimate on the lines of the inspection note which is used when writing out the job cards.

* * *

In addition to these preliminary investigations, the central progress office also deals with the following points :

e) *Distribution of labour between sections.*

In spite of the efforts made to distribute the work equally over the shops, the amount of work in each section varies more or less considerably day by day.

In order to strictly respect the specified dates of delivery, the central progress office has to keep a balance in each section between the amount of work to be done and the facilitaties for doing it.

With this object, the distribution offices report each day to the central office any unemployed or excess staff *for the next day.* This forecast is possible as the result of progress planning.

The central progress office makes the transfers required; it can draw on a certain amount of work for completion at a far-off date, or can employ available staff thereon.

f) *General control of the progress of the work.*

The general position in the shops is shown on works progress diagrams; only important work and the stages of progress are shown thereon. The central office is advised of any irregularities occurring in any section and so can deal with them at once.

II. — Carrying out the work (distribution office).

When the preparatory work has been done properly beforehand, the orders should be completed on the lines of the preparatory work.

Now, under the old working conditions the work was distributed by the assistant foremen and chargemen. The delivery times were not maintained, and the men responsible were always ready to explain

the mistakes and delays, though the excuses could rarely be proved.

The basic idea of the new organisation was that the control should be by a central authority which would issue work orders methodically and would be in a position at all times to see the work was progressing regularly. The distribution offices use for this purpose the planning system described below.

A. — Planning system.

This planning system is a graphical representation of the function of management. If the management is to be satisfactory we must :

1. Know the kind of work to be done and its importance, the time within which it must be completed as well as the chronological order of its successive stages;

2. Know what equipment, and men, whether working in gangs or individually, are available, etc.;

3. Have particulars at all times and in detail of the position of the two factors : *a*) work to be done, work which can be distributed, work already distributed, work started, and work ended, and *b*) number of men present, available, at work, or away on duty;

4. Make provision for distributing the work so as to be sure : *a*) that the work is completed within the time allowed; *b*) that the staff is fully employed and to the best advantage;

5. Know how the carrying out of the work is progressing, and any unexpected happenings; take steps to remedy these at once;

6. Collect the data required in connection with the study and improvement of the stop organisation; descrepancies between the schedule and the actual results; the formation of the gangs, mistakes in previsions, etc.

Too great concentration of mind nor too great an effort of memory should not be required of the men expected to have a knowledge of this information and to use it; the planning diagram shows this information in such a way that it speaks for itself and is easily and quickly read. These plannings are drawn up on squared paper (75 cm. = 29 1/2 inches) high, in diagrams each for groups or gangs of twenty to thirty men.

The diagrams are arranged in columns of 80 mm. (3 5/32 inches) wide, each corresponding to a day (8 × 10 mm. for each 8 hours).

Each diagram consists of two main parts : Progress planning and individual planning, the latter name indicating its purpose.

1. — *Progress planning.*

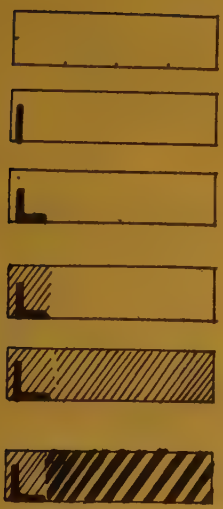
a) *Work undertaken to a standard schedule.* — The order in which such work must be done is laid down and every job usually has to be completed by a given date. In any case, each job must be completed before a predetermined date. Consequently for each job the *date* it must be done or the *time whithin* which the work must be done is known.

In progress planning the jobs are shown opposite the expected date of completion as *laid down in the standard schedule.*

b) *Work not done to a standard schedule (manufacturing orders, etc.).* — According to circumstances the progress office lays down the time the work is to be completed; most of such jobs have to follow a series of operations not unlike a standard schedule. The progress office specifies the time within which each operation is to be carried out. With the

PLATE V.

I. Progress planning.



2 men for 4 hours.

the work is prepared and can be taken in hand.

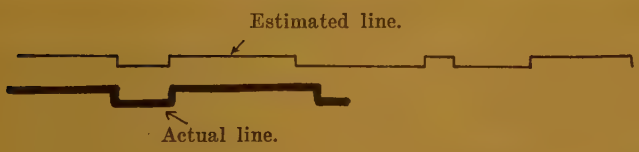
the workmen have been selected for the work.

work in hand.

work finished to time.

work begun to time but finished late.

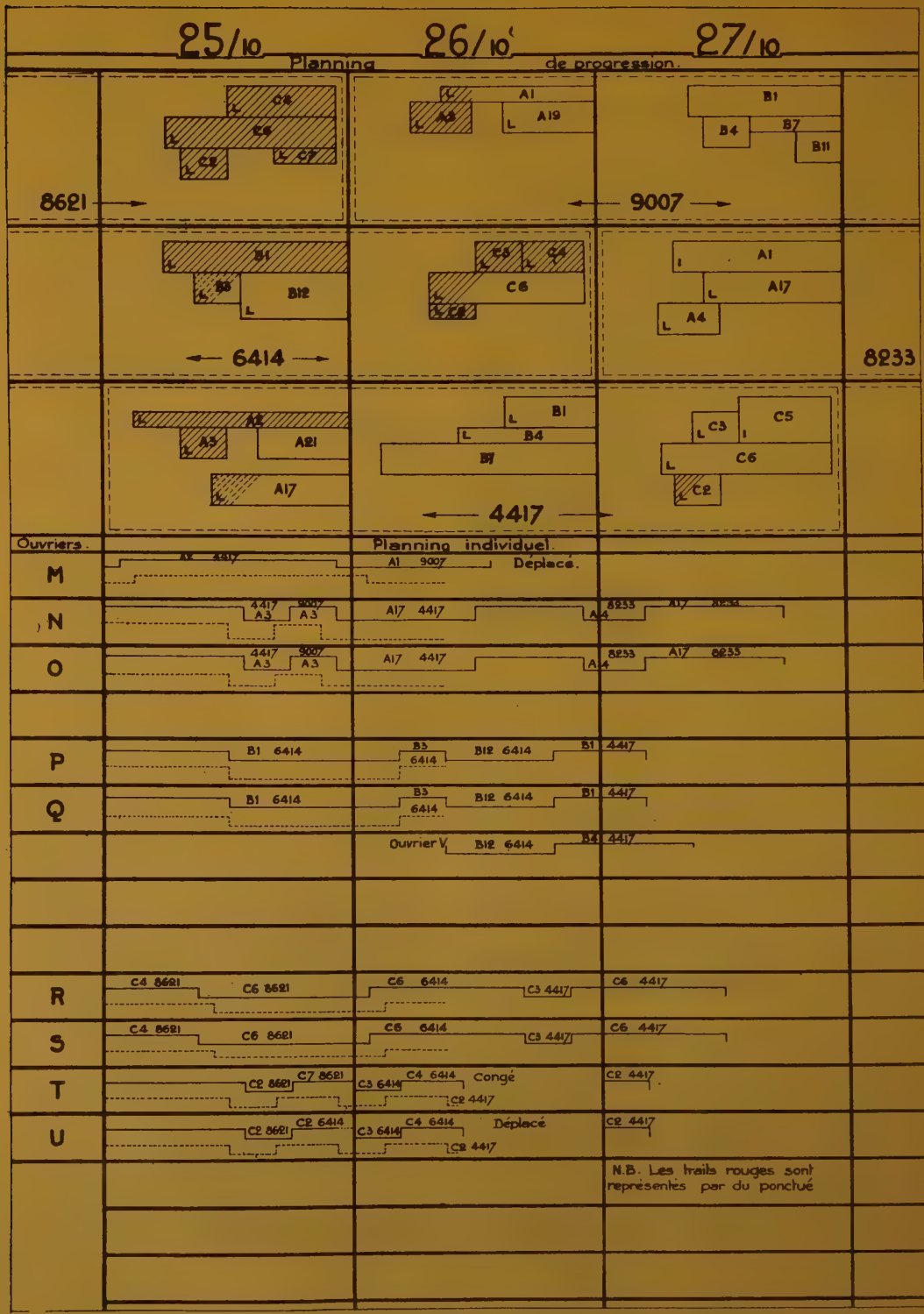
II. Individual planning.



Case in which the workman is behindhand on the timings.

Case in which the workman has made up time on the timings.

Explanation : Thin lines represent *black* lines on the planning.
Heavy lines represent *red* lines on the planning.



Explanation of French terms : Ouvriers = Workmen. — Déplacé = Transferred. — Congé = On leave.

N. B. — Red lines are shown dotted.

delivery date in mind, and the amount of work in hand, the planningman enters the job on the progress planning sheet against a date which becomes the date the job must be finished but which must not be later than the date given by the progress office. Any delay in completing the work starts from this latter date.

2. — *Individual planning.*

This planning is on the same diagram as the progress planning, and the dates are common to both.

The fixed part of a diagram gives a list of the workmen affected by the planning. Against each individual workman the different jobs he has to do are shown by conventional signs. *This distribution of work is done each day for the following day at least.* The work can be allocated several days ahead, but it has to be done daily to take into account the new work coming in and work completed.

The work done is also shown against each man by a second line in red. The times are those on the job cards as recorded by the recording clocks.

The chief *conventional signs* are given in plate V. The rectangle is the characteristic sign of the progress planning as it shows by its two dimensions the number of workmen at work and the time allowed them to do it. The progress of the work is shown by other signs (red pencil marks or black or red hatching according to the case); they are made as the work is ready to be taken in hand or as a workman (or a gang) has been instructed to do the job, or as the work is started, or finally as the work is completed, either to time or late.

The nature of the job is shown by the number of the vehicle and by the index used to show it on the inspection notes and on the job cards.

In the case of *individual planning* the different jobs given each man are shown by a series of straight black lines, the length indicating the time the work takes, the ends of the lines corresponding to the start and end of the job as laid down in the schedule.

The successive jobs given the same man are shown by the steps in the lines representing the work. The work done is shown by a succession of red lines. Other signs are used to take into account any particular features in the distribution of the work and anything arising when doing it, such as delays in starting, time made up on the estimated period, forced interruption in doing the work, urgent work having to be taken in hand between booked jobs, etc.

As an example, if at any time the red line showing the work completed is much in arrears on the black line representing the schedule, the two lines are brought into agreement by drawing a dotted red line across the schedule line (plate V). Similarly, if a man is much ahead of the programme, some overlapping occurs in the black line (jobs 7 and 8, plate V).

The two plannings are linked together by the job number. In certain cases the number of vehicles under repair may be high enough to make it difficult to find the numbers. In such case, each unit is given a different colour instead of using black only, and this makes it easier to link up the two schedules. Red is, however, reserved in the progress planning to show work begun and finished late, and to show the work done on the individual planning diagram.

As an example, plate VI is part of a schedule for three days of a particular month.

The vehicles under repair, the time for which is three days under this particular

schedule, follow one another at the rate of one a day.

Vehicles 8621, 6414, 4417, 9007, 8233, etc., follow on one after the other.

All work on any one of these vehicles is shown in the corresponding rectangle.

Jobs A are done the first day, B the second, and C the third day.

The diagram shows the position on the 26th day of the month after three hours' work.

If everything were to plan, all jobs of the 25th of the month should be finished. The progress planning diagram shows straight away, however, that :

1. the work is completed on 8621;

2. on 6414 the job B3, started late, is in hand, and job B12 not started is covered by the individual planning;

3. in the case of 4417, job A17, started late, is in hand, while nothing has been done on job A21 as the preparatory work remains to be done.

On the 27th, there was another irregularity, as job C2 on vehicle 4417 was already started.

The individual planning (lower part of the diagram) has been designed so that work by specialists is clearly separated from the rest. The workmen M, N, O specialise on job A. The men P and Q deal with job B; as the progress planning shows that jobs B are behindhand, this gang is strengthened by adding V to it. Jobs C are carried out by R, S, T and U who are working in gangs of two.

The man T has leave off the afternoon of the 26th and as jobs C are in advance the workman U is also moved for the same period.

The individual planning shows at any moment how all the men are employed; for example, at the middle of the 26th day M is engaged on job A1 on vehicle 9007; N is working on job A17 of vehicle 4417, etc.

The work each man has to do is entered up beforehand up to the following day, except for the workman M, who is strengthening gang A for the moment.

When the schedule and the actual progress of the work are compared, we see workman M is late, whereas N and O, working together, are slightly ahead of the specified times.

B. — Time recording.

Formerly the time keeping was recorded by the chargehand entering on a black board, in chalk, hour by hour against each man's name, particulars of the order (number of the vehicle under repair, works order, etc.) on which the man was working; these figures were then booked in by time keepers.

There is no need to point out that under this system there was little guarantee that the allocations were made correctly.

At the present time recording clocks which automatically total up the working hours and deduct the time off duty, Sundays, and holidays, and all booked interruptions, are used. The mechanical time keeping in this way shows at any moment the total effective working hours without any possibility of fraud or error.

Each distribution office has a certain numbers of clocks which are operated by the time keepers. Their use has made it possible : *a)* to check the men at work; *b)* to check the time the various jobs take; *c)* to calculate the costs; and *d)* to calculate the wages and premiums.

a) *Check of men at work* : Each workman has a *workman's time card (Specimen F)* on which the time of coming on

SPECIMEN F.

BELGIAN NATIONAL RAILWAYS COMPANY.

LOCOMOTIVE AND ROLLING STOCK DEPARTMENT.

SHOP .....

Workman's "time" card.

Shop section : .....

Workman's number : .....

Workman's name : .....

Period from ..... to ..... 193 ..... Trade : .....

DAYS.	INTERRUPTIONS.		TIMING, ON DUTY AND OFF DUTY.	TIME.
To carry forward :				
Carried forward :				

duty and leaving work is stamped; these cards are classified in a special card index near the distribution office of the section; they are ruled on each side into days, each day being subdivided into two half days.

Irregularities recorded by the clock : late arrival, leaving work early, absences, which interrupt the work, are entered by the time clerk in a special column.

As a check, the section foreman draws up daily a list of all men away from work, which he gives to the time clerk to check against the time cards; it is then sent to the accounts office for checking and filing.

b) *Checking the work produced.* — A job card is issued to cover each job and is either for an *individual* man *(Specimen C)*, or a *gang (Specimen D)* according as the work is to be done by one man or a gang.

The job cards are filled in beforehand by the works order office; they then show : 1. the shop in which the work is to be done; 2. the number of the order or account; 3. the kind of work; 4. the time allowed (hours and hundredths of an hour); and 5. the rate number.

These cards are then filed at the distribution office in special cabinets in the order in which the jobs are to be done,

according to the planning schedule. The time keeper can, as a result, issue a job card quickly and be sure that the order of the planning schedule is being followed.

Each workman has a « *work* » card *(Specimen G)* on which all the work the man does in the month is entered, with the time taken; this card shows in detail how the man's time recorded on his « time » card has been used.

The « work » cards are filed in the distribution office close to the recording clocks.

When a man working alone finishes a job, he goes to the distribution office and hands in his job card. The time keeper takes the « work » card and the job card for the next piece of work to be done and stamps them at the clock.

The number of the job card is entered on the « work » card and also its allocation.

In the case of a gang, the times are stamped on the cards by a « work distributor », so as to avoid loss of time and output.

The way the men are occupied is therefore easily checked : each workman should always possess one job card only, and it should relate to the job in hand.

The « work » card ensures full occupation of the man at any time; it guarantees continuity of the work.

The completed job cards are sent to the accountants office where the « time » cards, « work » cards, and « job » cards are checked against each other.

The « job » cards are used to calculate the expenditure per vehicle; they are filed for this purpose by order number.

The premiums are calculated on the « work » cards; the pay sheets are based on the « time » cards.

Provision has been made to deal with special cases, such as illness, holidays, accidents, transfers, work carried out outside normal working hours, and when working several machine tools.

III. — Checking the progress and quality of the work.

a) *Progress.* — As we have seen, the distribution office, by means of progress planning sheets, controls the whole working of the shops; the planning schedules, by showing the state of affairs at any moment, give a picture of the progress of the work in each section.

The central progress office and each of the main distribution offices are controlled by progress foremen recruited from the supervisory staff by competitive examination. The main duties of these men is to take all necessary steps, in liaison with their colleagues, so that the work in their section progresses in accordance with the schedule in force. They make sure that the estimated times are brought to account in the progress planning, whilst adhering to the times of the standard schedules; that the job cards are taken into account in getting out the individual plannings, and that the total amount of work on the job cards is properly checked over daily; that all the men are kept fully employed; and that the work is distributed and carried out according to the schedules.

The progress of the work can be followed quite easily from the progress planning : if everything goes along normally, all the rectangles to the left of the ordinate representing the time the check was made should be wholly or partly cross-hatched; blank rectangles, sometimes without any sign relating to the distribution of work, show the delay at a glance. The production and the output of each man in particular can also be

Specimen G.

BELGIAN NATIONAL RAILWAYS COMPANY.

LOCOMOTIVE AND ROLLING STOCK DEPARTMENT.

D. C. O. No. 43A. - "Work" card.

SHOP : Malines Main Shop. Workman's No. : 363.

Section : Carriage-Turnery. Workman's name : N . . . . .

Period from the 1st to the 20th November, 1933. Trade : Turner.

No. of gang job card.	Order No.	Allocation.	TIME SPENT ON WORK AND INTERRUPTIONS. Interruptions to be deducted.	Times of actual working hours.	Time.
To be carried forward.					
1672	24923	3.75		11 03 16XI 99 30 o	
1192	24618	5.35		11 03 16XI 99 30 o 14 42 15XI 93 95 o	
1750	21765	2.75		14 42 15XI 93 95 o 10 57 15XI 91 20 o	
1733	24924	5.85		10 57 15XI 91 20 o 14 06 14XI 85 35 o	
1788	24824	2.35		14 06 14XI 85 35 o 10 45 14XI 83 00 o	
1714	21818	4.60		10 45 14XI 83 00 o 15 09 13XI 78 40 o	
1605	24821	4.05		15 09 13XI 78 40 o 10 06 13XI 74 35 o	
1695	17203	7.15		10 06 13XI 74 35 o 13 57 10XI 61 20 o	
1596	27118	1.45		13 57 10XI 61 20 o 11 30 10XI 59 75 o	
882	24569	1.20		11 30 10XI 59 75 o 10 18 10XI 58 55 o	
1347	24863	0.40		10 18 10XI 58 55 o 9 54 10XI 58 15 o	
Carried forward . .					

(Mechanisation).

followed by examining the individual planning.

The technical executive staff can follow the main stages in the whole of the repair work by means of a general progress board kept up to date by the central progress office from the information sent in daily by the various distribution offices. The work in the sections has become so regular, however, that this general board has lost much if its importance.

b) *Quality of the work.* — Regular progress of the work is closely linked up with good workmanship and careful inpection at all stages; otherwise contestations will constantly be experienced : The erectors will pretend the detail parts are badly finished off, whilst the turners will complain of the hardness of the steel or of the excess metal left on castings. In some cases the inspectors question the way a repair has been done or the working method resorted to, and in others definite bad work involves replacement and upsets the progress of the work.

The inspection has been organised on the following basic principle : Inspecting the quality of the work must be considered as a routine operation to be included in the operations listed by the inspector; it should be covered by a job card and be taken into account in the progress planning.

For this purpose :

a) The details must be inspected as often as needed, and in principle after each operation;

b) The necessary steps must be taken whenever defective work is discovered;

c) The machining tolerances (length, diameter, bore, etc.) allowed for each part, must be laid down beforehand;

d) The way the inspection is to be carried out should be laid down in detail and special equipment provided (gauges, surface gauges, compasses, etc.) where not available;

e) the place and time at which each inspection is to take place should be laid down.

This inspection is carried out by men selected from the workmen; all parts passed or rejected are stamped, the mark being surrounded by colour to make it easily found.

As an example, plate VII shows one of the inspection sheets used on the connecting and coupling rod secondary belt; we will, moreover, return to this when dealing with the belt organisation.

IV. — Staff of the progress office.

As a result of the new organisation, the staff establishment has had to be altered considerably.

The following table gives the composition and duties of the new staff of the progress office. Is has been found possible to draw all this staff from the workshops, the ability and knowledge of each man selected being taken into account.

The supervisory staff of the shop, the foreman and chargehands retain their supervisory duties as regards the actual carrying out of the work and policy in the shop; they keep in the closet touch with the progress office.

Finally the leading shop hands, few in number, distribute the work to the men in their gang, as laid down by the progress office; in certain cases they act as specialists for such work as measuring up, marking off, etc. As selected men, they watch the way the work is done, both as regards quality and speed; they see the job cards of their gang are stamped to save the men leaving their job and losing time.

Name of office.	Title.	Grade of men.	Duties.
Central progress office.	Chief progress man.	Chief progress man.	Investigation into and control of the organisation.
	Inspectors.	Leading hands.	Inspection as regards materials and labour.
	Men preparing the work.		Preparation of estimates; writing out repair and manufacturing operation slips.
	Time takers.	Skilled workmen.	Timing studies.
	Checkers.		Checking quality of work.
	Bookers-in and time keepers.	Unskilled workmen.	Writing out job cards; various returns, reports, etc. Writing out stores cards.
Distribution offices.	Chief progress man.	Chief progress man.	Investigation into and control of the organisation.
	Planning men.	Skilled workmen.	Following up progress planning.
	Time keepers.	Unskilled workmen.	Filing job cards and stamping them at the recording clocks.

However, this supervisory shop staff is in no case allowed to give any order not in entire agreement with those of the progress and distribution offices, as these alone are allowed to actually control the production.

V. — Results obtained.

Obviously, this organisation was not carried through without difficulties and opposition.

The boiler shop was first of all tackled, as this is the nerve centre of locomotive repairs. The repair notes, rates, tables of work in hand, timing, progress planning diagrams, and card indexes were altered and improved many times before a simple, effective, and practical solution was arrived at.

When the boiler shop was reorganised, it was the model on which to reorganise in turn the other shops : underframe, tender, forge, turnery, etc.

As regards the staff, apart from some difficulty through some of the older men not being able to adapt themselves easily to the new methods, they as a whole readily took to the new ideas; it was found possible to recruit, from the supervisory staff, men of outstanding ability for the progress offices.

A large number of the workmen willingly collaborated in the reorganisation. Some of them assimilated the new methods in an astonishingly quick way.

We have given particulars of the staff of the progres offices; it may be questioned whether such a large establishment of non-productive staff does not increase the final cost price. This objection would appear justified, seeing that

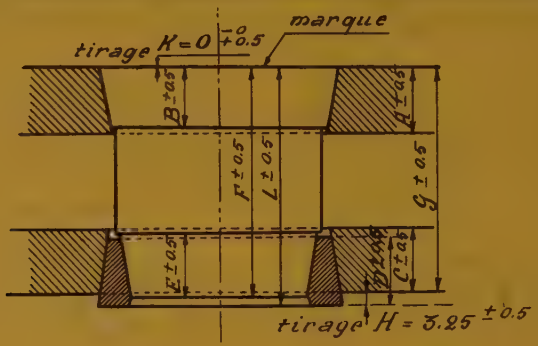
Malines Main Repair Shop.

Locomotive type : $\frac{64 - 81 - 90}{C - 3}$

Inspection Department.

Belt : Rods.
Inspector No. 3.

Operation to be inspected : Turning of pins and coned rings.



Note : Tirage = draw. — Marque = mark.

Pin N°	G	A	C	F + G + 1	B = A − 1.75	E = C + 0.25	D = C + 0.25	L = G + 3.25
1								
2								
3								
4								
5								
6								

Dimensions to be checked.	Dimensions according to drawing.	Play according to drawing.	Tolerances.	Drawing No.	Remarks.
1. Length of pin F according to measurement slip . . .			± 0.5		
2. Height of cones B and E do. . . .			± 0.5		
3. Length of pin and ring L do. . . .			± 0.5		
4. Thickness of coned ring D do. . . .			± 0.5		
5. Draw of pin K	0		− 0 + 0.5		
6. Check coned bearing of pin			condition		
7. Draw of coned ring H	3.25		± 0.5		
8. Check coned bearings of ring : play allowed . . .			0 4		
9. Diameter of cylindrical part for new pins	80 - T. 81-64-90 100 - T. 90		gauges gauges		

Tools.

1 micrometer gauge to 50ths.

1 80-mm. gauge with tolerances of $\frac{-0.1.}{-0.05.}$

1 100-mm. gauge with tolerances of $\frac{-0.1.}{-0.05.}$

1 thickness gauge 0.04.

	Preparation.	Doing the work.
Time allowance per pin		

The technical employee :

The Engineer :

the numbers found to be necessary in practical service are :

Inspection and preparation :
1 man for about 50 workmen;
Bookers in :
1 man for about 85 workmen;
Planning and time keeping :
1 man for about 40 workmen;
Inspection :
1 man for about 50 workmen;
Chargehands :
1 man for about 30 workmen;
Miscellaneous :
1 man for about 200 workmen,

that is, in all, about 12 men for 100 workmen with, in addition, a certain number of assistant foremen, foremen, and accountants.

Against this, the chargehands required under the old organisation have been done away with; there was a leading hand for every 8 to 10 men, so that the proportion was roughly the same as the above.

A considerable though temporary expenditure had to be incurred only in organising the timing service, and in getting out estimates and standard schedules.

The results obtained actually exceeded the most optimistic expectations.

The average repairs cost has fallen considerably. The output is almost absolutely regular, and the total time the vehicles are stopped has been reduced to the extent we have already mentioned.

As a result of the planning system, each man is kept fully employed, there is no loss of time between jobs, the workman never has to wait nor to look for the parts he has to work on, and the work is carried out without any interruption.

The timing of operations has reduced the costs. Investigations into tool equipment and manufacturing methods, and the determination of operation times have produced great savings on the operations themselves.

The result of checking the quality of the work done and introducing limits of wear and tolerances has been to raise the standard of the repair work.

The results given below have been obtained in the locomotive section and relate to heavy repairs to 0-8-0 goods locomotives.

In 1931, the heavy repairs of such a locomotive took 5 380 man-hours; the total cost including general charges was 134 000 francs and the time 45 working days. In 1934, the figures have become : 3 700 man-hours, 93 000 francs (1) and 20 working days respectively.

There has been, therefore, a very marked improvement in the output of the men carrying out the actual repair work, although there has been some set-off in the labour used in the new organisations, the cost of which is included in the total cost, and this, in the end, is the basis by which to see the results of the reorganisation.

The reduction in the cost price, even when the fall in wages and cost of materials is taken into account, remains considerable. In addition, the time the locomotives are out of service has been reduced by over 50 % in three years' time, and this, from a financial point of view, must by no means be overlooked.

The results therefore are most interesting, and prove the progress made possible by adopting up to date methods of organisation.

(1) This figure of 93 000 francs would have been 117 500 if the wages and materials costs had remained at the 1931 level.

(To be continued.)

[625. 122 (.44) & 625. 173 (.44)]

Re-making and blanketting clay formations under main lines in service,

by Mr. GIRAL,

Divisional Chief Engineer, Alsace-Lorraine Railways.

(The Railway Engineer.)

The cleaning or re-making of the railway formation in clayey ground has always been a troublesome and expensive problem. The most satisfactory treatment is generally to dress the formation down to sound ground, fill stone holes with pug and provide for the run-off water, and then apply a layer of fine material on which the ballast is laid. This method has been used on 33 sections of line in Lorraine with complete success, the length of track involved exceeding 19 miles. Formerly, the procedure was to remove one track at a time, meanwhile working all traffic on the other line, including the supply of slag and ballast. Recently, however, a new method has been employed, which eliminates the cost and delay occasioned by single-line working and effects a saving of about 50 000 fr. per track-km (say, £ 1 000 per track-mile) treated. The method consists essentially in lifting a length of the rails complete with sleepers, by means of special tackle. The formation being re-made and blanketted, the track is replaced by the same means and regular service is resumed. One or more sections of track per diem can thus be dealt with during an interval between trains of not less than 1 1/2 hours.

The first operation is to lift a length

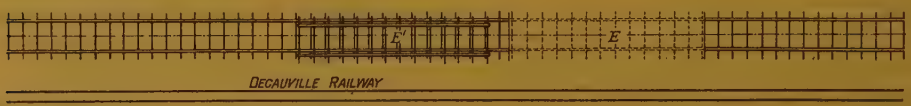


Fig. 1. — A complete section of track is lifted from E, transferred to E^1, and replaced after re-making and blanketting the formation.

of track from *E*, figure 1, and transfer it temporarily to a position about *E'*. This is accomplissed by means of trestle-mounted chain winches which lift the track and enable it to be run along loose rails laid down for the purpose. Referring to figure 2, two pairs of cross rails *T* are inserted beneath and packed up to the running rails. Immediately after the passage of the last train, the fishplates are removed at the ends of the length of track to be lifted, trestle-mounted winches are placed on the rails *T* at *A*, *B*, *C*, *D*, and the running track, complete with sleepers, is lifted by about 400 mm. (1 ft. 3 3/4 in.). During this operation, rollers are attached to the flanges of the rails as shown in figure 3, which also shows the details of the lifting winches and clamps. These rollers are attached at *A'*, *B'*, *C'*, *D'*, figure 5, and longitudinal rails *L* are placed beneath them; the suspended track is then lowered until the rollers rest on the rails *L*, after which it is pushed to the position *E'* (fig. 1). It should be noted that

figure 5 actually relates to the reverse process of re-turning of the track to the cleaned and prepared formation.

The whole operation of lifting and removing the track can be completed in about 5 minutes, after which the ballast

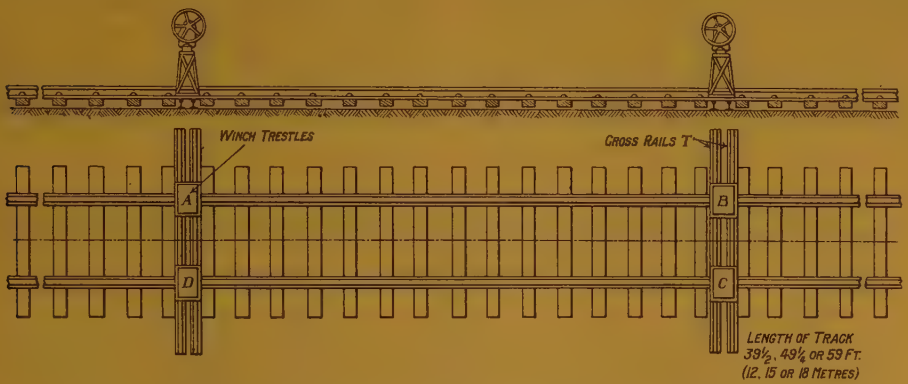


Fig. 2. — Cross rails and winches in place, preparatory to lifting the track.

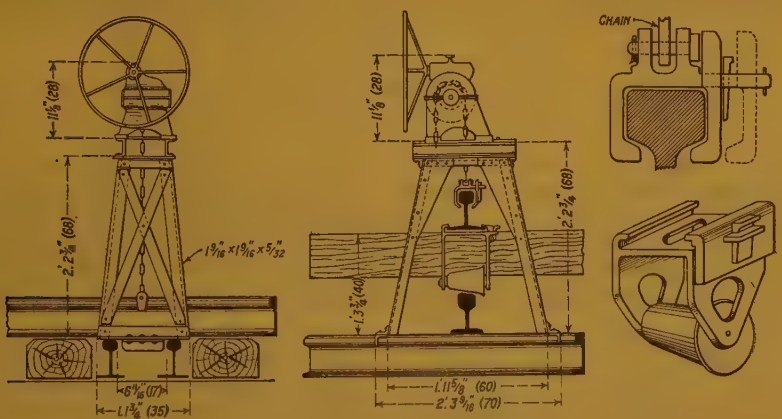


Fig. 3. — Showing details of the winch trestlest, lifting clamps, and carrying-roller attachment.

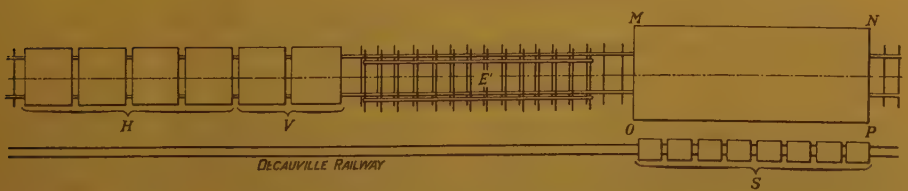


Fig. 4. — Spoil removed by Decauville railway and ballast train waiting on main line.

is removed from the vacated area *M N O P*, figure 4, and the clay subsoil is dressed to a slope of 1 in 25 towards the ditch, holes formed by the removal of projecting stones being filled with pug. The material removed is loaded into trucks *S* on an adjoining temporary Decauville railway. Meanwhile, a ballast train is backed along the main line with two flat trucks *V*, figure 4, loaded with fine slag or ashes or sand, and a sufficient number of hopper wagons *H* containing unscreened slag or large ballast. The fine material is unloaded into Decauville trucks, taken alongside *M N O P* and spread evenly over the new formation. A series of cross rails *T* mounted on stacks of cut sleepers are then placed

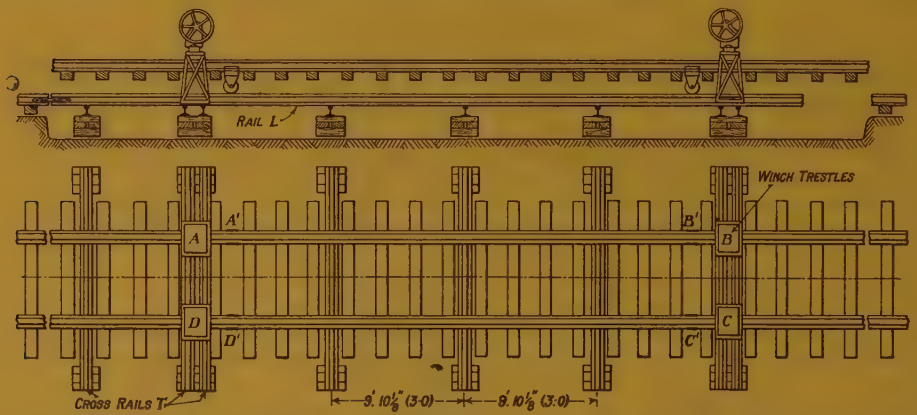


Fig. 5. — Showing track returned on temporary supporting rails, the formation having been re-made and blanketted.

in position, as shown in figure 5, to carry two longitudinal rails *L* along which the track is wheeled back to its original position. The track is lifted slightly, to permit the removal of the rollers, and then appears as shown in cross section by figure 6. After removing the rails *L*, the track can be lowered on to the cross rails *T* and the fishplates at each end can be replaced. Continuity of the main track being thus restored, the train of hopper wagons containing the unscreen-

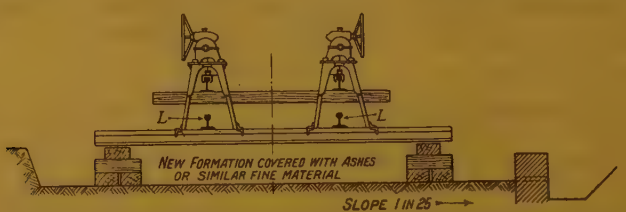


Fig. 6. — Cross section of track ready for lowering on to cross rails as soon as the longitudinal rails L are removed.

ed slag can be backed on to the re-laid track and unloaded on to the blanket of ashes. Finally, the cross rails and their supports are removed, the slag is packed well beneath the sleepers, and the track is ready for service under a speed restriction until after a time, depending on the traffic and other conditions, it is suf-

ficiently well packed and consolidated to permit of full speed running.

If the line can be closed to regular traffic for 2 1/2 hours, two lengths of track can be removed at once, one being taken to each end of the section concerned. It has, in fact, been found possible on the Alsace-Lorraine Railways to deal with two 15-m. (49 1/4 ft.) sections a day, either during two 1 1/2-hour intervals or one 2 1/2-hour interval. This rate of treatment, 98 1/2 feet of single track a day, is exactly twice that obtained under the old system of temporary single-track operation. By working on both tracks a daily advance of 197 feet has been maintained during recent months, with the further advantage that costs are reduced by using a single ballast train to bring material for one track in the morning and the other in the afternoon. An appreciable gain in efficiency results from the fact that the permanent-way men have the same amount of work to do each day; and the formation benefits by being immediately covered with slag instead of being left exposed for several days, as often happened under the former system.

[625. 142.2 & 625. 142.3]

Evolution of wear-resisting rails.

The martensitic rail of the Eisenwerkgesellschaft Maximilianshütte,

by Cecil J. ALLEN, M. Inst. T.

(*The Railway Engineer.*)

In service, railway rails have to serve the double purpose of carrying the weight of the traffic, and acting as guides for the wheel flanges. Each rail is thus stressed and gradually worn by both vertical and transverse loads. The area of contact between rail and tyre is relatively small and the loading of the rail tread correspondingly great. As the wheel loading increases, the yield point of the rail steel may be exceeded, resulting in a crushing of the surface. The effects of the side thrust on the rails due to the guiding of the wheel-flanges are, however, more important. Even on straight track, the « elbowing » or « nosing » of the locomotives and vehicles may result in considerable lateral stressing of the rails as the speed increases, but a far greater lateral loading occurs, of course, on the inside of the head of the outer rail on curves under certain conditions,

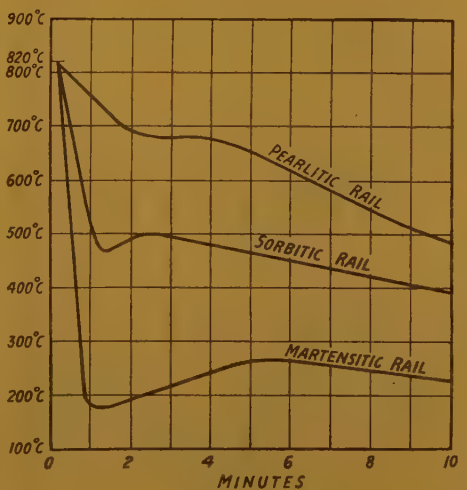


Fig. 1. — Temperature-time curves relating to the manufacture of pearlitic, sorbitic and martensitic rails.

resulting in severe abrasion or « side-cutting ». Higher speeds are here of predominant importance, for the centrifugal force increases with the square of the speed; and on curves there is, in addition, a certain slip at the wheel tread and flange, adding further to the abrasive effect. Increased resistance of rail steel to wear has hitherto been sought in the following three main directions :

1. Rails of ordinary carbon analysis or of alloy steels, in which the head, web and foot are of the same metallic structure.

2. Compound rails, in which the head is of extremely hard steel, while the web and foot are of mild steel quality.

3. Heat-treated rails, in which the advantages of compound rails are obtained by some form of quenching treatment applied to the head alone.

Compound rails.

The different functions fulfilled in service by the head of the rail, on the one hand, and the web and base, on the other, suggest that the head should be made of hard, wear-resisting steel, while the web and base are of softer and tougher material. This consideration has led to the compound steel rail, whose forerunner, in the days of wrought iron, was the so-called steel-headed rail. Compound steel ingots are poured in an ordinary ingot mould by a special process. In present-day Continental practice, which is on a very limited scale, high carbon alloy steel of very hard quality, with a tensile strength of 110-140 kgr. per sq. mm. (70-89 tons per sq. inch.), is teemed on one side of the ingot and soft, ductile steel at the other; these ingots are then rolled so that the rail head is of the hard steel, and the web and base of soft steel. The ingots may be cast by pouring simultaneously into a mould with a thin perforated partition from two ladles, each containing different qualities of steel, which then diffuse at the boundary (the partition itself melting) and produce a smooth transition from soft to hard. Alternatively, hard steel may be poured into an ordinary mould fitted with a cooling plate, which is removed when the metal has solidified; the soft steel is then poured in to fill the mould and the melting and welding action at the surface of the hard steel effects, it is claimed, union and smooth transition between the two zones. The utmost care is required in manufacture, both in teeming the metal into the moulds, and in the rolling, while close attention is also required in cooling, in order that the very hard alloy steel in the rail-head may not fissure, and that strains set up in the rail, owing to the presence in it of two steels of widely differing physical properties, may not cause failures in service.

Heat-treated rails.

Experience shows that freedom from brittleness may be reasonably assured in the case of heat-treated rails when the steel is, in itself, soft and tough. The effect which was formerly produced in soft rails by the work-hardening of the running surfaces can now be produced in advance by heat treatment, by utilising the valuable characteristic of carbon steel that its microstructure and physical properties, particularly its hardness, can be greatly modified by suitable heat treatment. Three processes in particular for the heat treatment of rails have now been perfected on a commercial scale : the British Sandberg process, the French Neuves-Maisons process, and the German process of the Eisenwerkgesellschaft Maximilianshütte, of Rosenberg, Bavaria. The Sandberg and Neuves-Maisons processes effect a relatively smooth and gentle cooling, which produces a sorbitic structure in the head of the rail, whereas

Fig. 2. — Thirty-metre (98.4-foot) rail traversed from the sawing line rollers and held by notches in the cooling bank, base uppermost. Carrier frame ready to grip rail.

the Maximilianshütte process depends on a sharp and rapid quenching of the railhead in a stream of flowing water with a view to producing a martensitic structure — the hardest attainable structure — on the running surface of the rails.

At high temperatures, above the critical range, the carbon in steel is in the form of iron carbide or cementite in solid solution, which is known as the austenitic condition. Normal slow cooling through the critical temperature range results in conversion of the structure into pearlitic steel, consisting only of ferrite and pearlite. Pearlitic steel is soft, and carbon steel rails which cool normally after rolling possess only the natural hardness corresponding to their carbon content. If the steel is cooled more rapidly from a temperature above the critical point, however, so that there is not time for the conversion of the dissolved iron carbide into soft ferrite and pearlite, then the cementite is more or less completely retained and the steel is correspondingly harder. This principle is applied, in all the three processes just mentioned, to the hardening of the running surface of the rail-heads by sudden cooling. The curves in figure 1 show typical rates of cooling of rails from the same temperature, slightly above the critical point, according as the rail is cooled normally in air, to produce a pearlitic structure throughout; more rapidly by the Sandberg or Neuves-Maisons process, for the production of sorbite; or as quickly as possible by quenching in water, resulting in the production of martensite, as in the Maximilianshütte process.

Sorbitic rail treatments.

The Sandberg process has already been described very fully in *The Rail-*

way Engineer and most recently in the March, 1931, issue (1). In this process, accelerated cooling, from a temperature slightly above the critical point, is effected by a mixture of air and water which is blown against the head of the rail in the form of a dense mist through closely-spaced atomising jets. The sorbitic structure so produced in the railhead can generally be relied on to give a tensile test of more than 60 tons per sq. inch, with an extension of 15 %, or more on a 2-inch gauge length. In the latest development of this process the earliest stage of the cooling is accelerated by increasing the head of water passed through the jets, and some remarkable tests have been obtained on rails so treated, as expressed in the combination of even higher tensile tonnages and extension percentages than those just mentioned. The tonnage of rails which has been heat-treated by the Sandberg process to the present date is far greater than by any other process, and such rails are giving satisfactory service in all parts of the world.

In the Neuves-Maisons process, which also produces sorbitic rails, the railhead is dipped repeatedly in a trough of water, the quantity of water being limited and definitely proportioned to the weight of the rail. This results in an increase in hardness of the running surface of the railhead to between 63 1/2 and 70 tons per sq. inch. A detailed description of this process and the results obtained is to be found in the *Revue de Métallurgie,* 1926, N° 2, pp. 65-81.

The Maximilianshütte Martensitic process.

As previously mentioned, the Maximilianshütte process uses the quickest possible cooling of the rail-head in order to obtain a maximum degree of hardness by the formation of a martensitic structure, and the rapid quenching in water reduces the temperature of the head of the rail from 820° C. to below 200° C. in about 1 minute, as shown in figure 1. The rail is then removed from the water, and its hardened upper surface is normalised to some extent by heat flowing from the interior of the head, as witness the rise in the temperature curve, so that there remains a modified martensitic structure of extreme hardness, yet tough enough, it is claimed, to withstand the conditions of railway service. It is probable that as a result of the modification mentioned, this structure approximates more closely to troostite — the next lower structural range — than to the full martensitic condition.

The actual processes of hardening are illustrated by the accompanying photographs. The hot rail, cut to the usual length of 15 or 30 metres (49 ft. 2 1/2 in. or 98 ft. 5 in.), is turned upside down, as shown in figure 2. A frame suspended from a travelling crane then grips the upturned base of the rail by means of a number of pairs of tongs, which hold the rail firmly and keep it straight. As the clamps, of which there are seventeen pairs in the equipment illustrated, close on the rail, they remove any curvature due to cooling. The rail is now carried to the water trough and dipped (fig. 3), so that the outer surfaces of the railhead are submerged, but the fishing angles under the head remain clear of the water, This is brought through a large pipe at the bottom of the trough, the water flowing upwards through small openings and being directed by suitable guides towards the middle of the rail head, as is seen also in figure 4. Surplus water flows over the rim of the trough. The water in the trough is thus kept in motion, preventing the formation of steam bubbles on the surface of the rail, and ensuring the uniform hardening

(1) See also *Bulletin of the Railway Congress,* October 1931, p. 846.

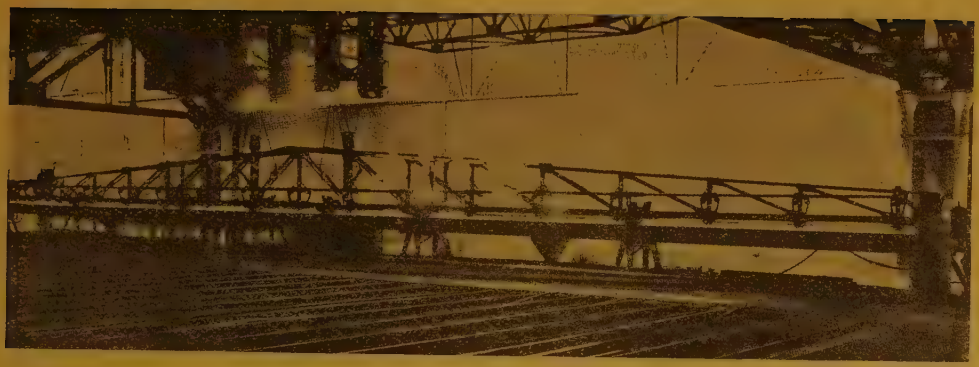


Fig. 3. — Head of rail immersed in water for hardening.

Fig. 4. — Hardened rail about to be secured to the arch (or bow frame).

of the head. The period of immersion of the rail depends on the carbon content of the steel and on the desired degree of hardening, and can be varied from a tensile strength of 120 to 140 kgr. per sq. mm. (76 to 89 tons per sq. inch). After quenching, the rail is fixed by the head to an arch or bow frame (fig. 5), and straightens itself as the base of the rail cools. Final straightening is then effected in the usual way by a straightening press.

The equipment described provides only for the hardening of one rail at a time, and would require to be in duplicate or triplicate for the simultaneous hardening of several rails from the same ingot. Figure 5, however, shows a device for the simultaneous hardening of three 30-metre rails; moreover, no crane is

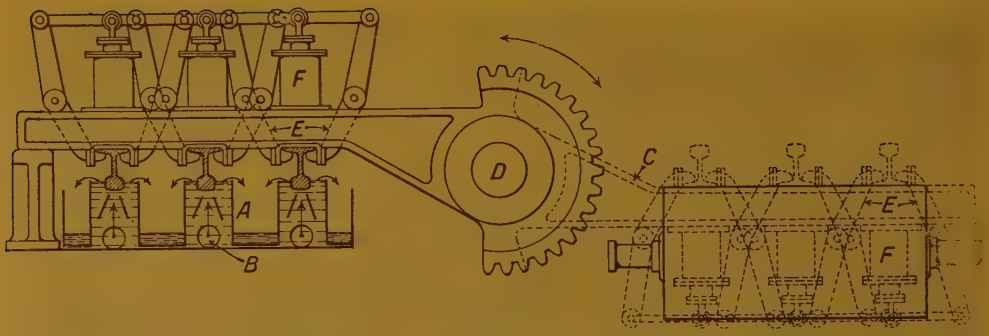


Fig. 5. — Equipment for the simultaneous hardening of three rails.

required. Between the live rollers of the main mill roller-train a number of movable arms *(C)*, which can be turned through an angle of 180° by the shaft (*D*), are arranged. Three rails, cut to length and coming from the same ingot at the same temperature, are carried into position by the live rollers, and clamped by the tongs *(E)*, actuated by the cylinders *(F)* underneath. The shaft *(D)* is then turned through 180°, bringing the heads of the three rails, now inverted, simultaneously into three water troughs *(A)*, fitted with water-supply pipes *(B)* and flow-directing plates as already described. On the completion of the hardening period, the shaft *(D)* is turned back to its original position, the tongs are released, and the hardened rails are carried forward by the rollers while another three are brought into position for treatment. An equipment of this kind is capable of dealing with the whole output of a large rail mill.

[621. 132.3 (.73)]

Recent American express locomotives,

by E. C. POULTNEY.

(*The Engineer.*) (*)

In 1919 the writer contributed an article to *The Engineer* in which a description was given of modern express passenger engines employed on the leading railways of the United States at that period, and at the same time he briefly noted some of the distinctive features found in American practice (1). During the intervening years which have passed between the date of the earlier review and the present time many changes have taken place, brought about mainly by demands for greatly increased power now required to handle heavier trains at high speeds, coupled with improved operating efficiency. In addition there has during more recent years been a distinct tendency to augment the length of locomotive runs. In order to satisfy such requirements involving the working of passenger trains weighing

(*) The printing blocks used for the illustrations in this article were kindly lent by the Editor of *The Engineer*.

(1) *The Engineer*, May 30th and June 6th, 1919.

upward of 1 000 tons behind the tender either at high speeds over medium-grade lines, or unaided over heavy grade divisions at lower mean speeds, has caused the introduction of engines of high power and necessitated methods of construction both novel and interesting.

It is the writer's present purpose to draw attention to the trend of modern American practice by illustrating examples which typify recent designs covering the six-coupled and eight-coupled types, as now used on some of the principal railway systems.

Locomotive types.

One of the outstanding features which characterise modern high-powered locomotives is the large boiler capacity provided, and it is this that has brought about modifications in the wheel arrangements now in evidence, compared with the prevailing practice at the time the earlier review was written. Formerly the majority of locomotives built for fast passenger services were of the *Pacific* type, having the 4-6-2 wheel formation, but the same reasons which made it necessary in the earlier stages of development to change from the 4-4-0 to the *Atlantic*, and from that to the *Pacific*, have in turn led to a modification of the latter, and produced the 4-6-4 arrangement, while at the same time the *Mountain* or 4-8-2 is giving place to the 4-8-4 type now found, more especially where the conditions imposed by the combination of heavy grades and increased train loads are to be met.

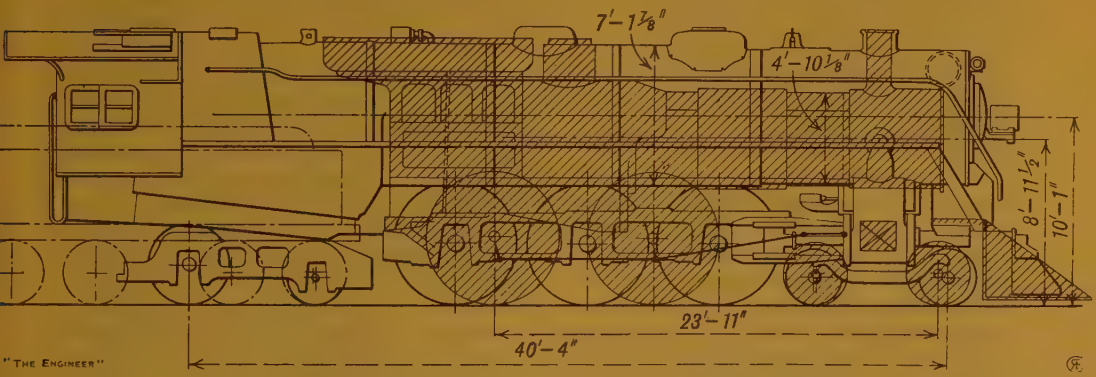


Fig. 1. — Comparison of 1893 locomotive with 1933 locomotive.

The maximum tractive effort available at starting is, of course, governed by the weight resting on the coupled axles, together with the cylinder dimensions and steam pressure, but at speed the ruling factor is steam production, and to maintain the power now required has necessitated the provision of increased heating surfaces and larger grates.

With both the *Pacific* and the *Mountain* designs, considerable heating surface is attainable, but in the matter of fire-box and grate area, and in the latter in particular, the limit is set by the weight that can be supported by the trailing truck. In certain instances very powerful engines of the *Pacific* type may be employed, owing to high allowable axle loading for the coupled axles, thus relieving the single trailing axle; but this is not always so, and in general individual weights on the coupled axles do not exceed a maximum of 70 000 lb.,

especially for fast passenger traffic, because of the increased rail loading caused by the dynamic augment at high speeds. The four-wheeled trailing truck has helped materially in this respect on account of its greater weight-carrying capacity, which enables the load on the drivers to be kept to that required for a safe adhesive factor only.

The tables giving the general dimensions and principal ratios of modern locomotives accompanying this article show that though the 4-6-4 and 4-8-4 are heavier than the 4-6-2 and 4-8-2 engines, the loads carried per axle are lower, and that the percentage of the engine weight carried by the driving wheels is not so high, but at the same time an adequate adhesive factor is maintained.

When considering these features, and especially when comparing the relative tractive efforts, it will be seen that the tractive effort of the 4-6-4 and 4-8-4 engines is not greater than for the 4-6-2 and 4-8-2 designs, but the increased boiler capacity enables these engines to generate much more power at high speeds, and, as will later be shown, it is now possible to develop 1 000 I.H.P. per coupled axle.

In carrying further a comparative study of these locomotive types it will be seen that the four-wheeled trailer has made it possible to provide grate areas proportionate to the larger heating surfaces, that the engine weight per square foot of combined heating surface is generally rather lower for the modified *Pacific* and *Mountain* designs, and further, more heating surface is provided in relation to the cylinder power, as shown by the boiler demand factors. This increase in heating surface in proportion to the cylinder capacity, together with the larger grates made possible by the introduction of the four-wheeled trailing truck, are directly responsible for the high sustained powers developed by modern 4-6-4 and 4-8-4 engines.

Boilers and superheaters.

Beyond an increase in size, boiler construction has not changed materially, though the higher working steam pressures now general have directed attention to the use of special steels with weight reduction as an object.

Usually, the fire-box is formed with a combustion chamber extending forward into the barrel section, and Nicholson thermal syphons are very frequently applied, both in the fire-box itself, where they form a support for the arch, and in the combustion chamber.

One constructional feature of interest is the now very usual practice of welding together all the plates for the internal fire-box and for the combustion chamber. The tubes and flues are also welded into the rear tube sheet.

All locomotives, as a matter of course, use superheated steam, and whereas formerly the type A equipment was commonly employed, the type E superheater is now very largely used. This superheater has much larger heating surfaces and, moreover, forms a greater proportion of the boiler, for, compared with the type A with a heating surface equal to about 20 % of the total combined, this figure for the E type superheater is about 30 %. In addition to the large heating surface, the flues housing the elements make up a greater part of the total free area through the boiler, which are therefore exposed to a larger proportion of the heat liberated by the fire-box. The use of this superheater has considerably increased the amount of superheat and improved cylinder efficiency and the power output.

Feed-water heating is receiving much attention, and, in general, all the most recent locomotives are fitted with feed heaters of the closed or open types, complete with pumps (2). The exhaust

(2) More than 90 % of the new locomotives built in 1930 were fitted with feed water heaters.

TABLE I. — **Examples of recent passenger locomotives of the 4-6-2 and 4-6-4 types.**

General dimensions and ratios.

Railway	C.R.R. of N.J.	B. & O.	Penn	So. Pac.	N.Y.C.	C.M. & St. P.	A.T. & S.F.	B. & A.
Type	4—6—2	4—6—2	4—6—2	4—6—2	4—6—4	4—6—4	4—6—4	4—6—4
Date	1931	1927	1929	1928	1931	1930	1927	1928
Cylinders, diameter and stroke, inches	26 × 28	27 × 28	27 × 30	25 × 30	25 × 28	26 × 28	25 × 28	25 × 28
Driving wheels, diameter, inches	74	80	80	73½	79	79	73	75
Boiler working pressure	240	230	250	200	225	225	220	240
Rated tractive force, lb.	52 180	50 000	54 675	43 660	42 300	45 820	44 900	44 800
Heating surfaces, sq. feet :								
Tubes and flues	3 190	3 452	3 980	3 069	4 203	3 794	3 842	4 203
Fire-box	401	394	305	283	281	411	314	281
Total evaporative	3 591	3 846	4 285	3 352	4 484	4 205	4 156	4 484
Superheater	1 000	932	1 634	836	1 951	1 815	980	1 951
Combined	4 591	4 778	5 919	4 188	6 435	6 020	5 136	6 435
Grate area	84.3	70.3	69.89	70.5	81.5	80.0	88.0	81.5
Weights, lb. :								
On drivers	205 900	201 000	207 600	187 700	187 000	189 720	198 400	187 500
On leading truck	63 830	63 000	54 200	61 800	65 000	79 930	65 300	65 000
On trailing truck	64 100	62 000	56 900	63 800	100 000	106 200	85 800	100 500
Engine total	333 830	326 000	318 700	313 300	352 000	375 850	349 500	353 000
Tender	253 900	214 000	245 000	291 100	302 700	289 150	287 000	204 600
Locomotive	587 730	540 000	343 200	604 400	654 700	665 000	636 500	557 600
Ratios :								
Weight on drivers, % of total	61.67	60.6	65.2	59.8	53.2	50.5	56.8	53.1
Engine weight ÷ combined heating surface	72.71	68.2	53.7	74.9	54.6	62.4	68.0	64.9
Adhesive factor	3.94	4 02	3.8	4.3	4.42	4 14	4.42	4.18
R.T.F. × diam. of drivers ÷ combined heating surface	841	837	737	766	519	602.5	638	522
Superheat surface, % of combined h. s.	21.8	19.5	27.6	20.0	30.3	30.15	19.1	30.3
Combined heating surface ÷ grate area	54.46	68.0	84.5	59.4	79.0	75.2	58.4	79.0
Superheater type	A	A	E	A	E	E	A	E

steam injector has also been fitted to some extent; that used is known as the Elesco pattern, which is a modification of the Metcalf design. The Sellars injector is also used, but so far as the writer is aware, the feed-water heater with pump, the latter either of the reciprocating or rotary (turbine-driven) description, is much the most common. Feed heating with exhaust steam is held to improve fuel performance, and add to boiler capacity, and, further, as about 12 or 15 % of the exhaust steam from the main cylinders is recovered for feed purposes, the equivalent of added tank capacity is obtained.

An examination of modern engines shows that there is a tendency to fit the regulator or throttle valve in the smoke-box where it can be arranged between the superheater and the steam chests. This permits the auxiliaries, including the air compressors, feed pumps, and the booster and stoker engine to use superheated steam, whilst, as steam is always in the elements, they are protected against overheating when the throttle is closed. Furthermore, dampers, which would be inconvenient to fit in conjunction with the type E superheater, are unnecessary. For the purpose of isolating the superheater from the boiler, a shut-off valve is usually fitted to the steam pipe in the dome.

There is a decided tendency towards higher working steam pressures which range between the limits of 200 lb. and 275 lb. per sq. inch, while, experimentally, pressures of as much as 300 lb. have been tried in the normal type of boiler. Generally, however, pressures of 225 lb. or 250 lb. are found, and the Pennsylvania, after employing as standard for many years a pressure of 205 lb. has adopted 250 lb. for its most recent designs. The Chicago and North-Western has in service a number of very large 4-8-4 passenger engines operating at this figure, but the boilers and machinery are so constructed that the pressure may be raised to 275 lb. if required.

Cylinders, main frames, and running gear.

The high power of modern engines has prompted considerable development work in the construction of the main framing to stand the stresses set up by the necessarily high piston loads, and the desire to reduce weight has been a further factor which has been instrumental in modifying the design and construction of both the cylinders and frames. Cast steel has been very largely introduced for cylinders, which are either cast with the half-saddle in this material, or in pairs in one piece with the saddle and valve chests complete. This type of construction has been used in conjunction with the usual separate frames with cross bracing members of cast steel, but the latest engines now have the whole of the main framing, including the cradle for the fire-box support and the cylinders, complete with piston valve chests, smoke-box saddle, and front bumper beam, with all brackets, made in one solid casting. In certain instances, the hind cylinder covers and the reservoirs for the air brake, have also been included, these being arranged between the side members and in the centre of the engine. Some of these locomotive bed frames have reached large proportions; for instance, those for some heavy 4-8-4 engines for the Chicago and North-Western weigh as much as 72 500 lb., or, say, 33 tons of 2 240 lb. Cast steel cylinders are lighter than cast iron, but are, of course, fitted with iron liners, as are also the piston valve chests.

As is well known, the two-cylinder engine is, for all practical purposes, universal in American practice, and all the designs now under notice are of this description. To obtain the high powers necessary, the cylinders must be of considerable size, and the diameters range generally between 25 in-

TABLE II. — **Examples of recent passenger locomotives of the 4-8-2 and 4-8-4 types.**

General dimensions and ratios.

Railway	Penn. R.	C.R.I. & P.	B. & O.	D.L. & W.	C. & N.W.	G.N.	D. & R.G.W.	C.M. & St. P.	A.T. & S.F.
Type	4—8—2	4—8—2	4—8—2	4—8—4	4—8—4	4—8—4	4—8—4	4—8—4	4—8—4
Date	1930	1929	1930	1927	1929	1930	1929	1930	1929
Cylinders, diameter and stroke, inches	27 × 30	28 × 28	27½ × 30	27 × 32	27 × 32	29 × 29	27 × 30	28 × 30	30 × 30
Driving wheels, diameter, inches.	72	74	74	77	76	80	70	74	73
Boiler working pressure.	250	200	250	250	250	225	240	230	210
Rated tractive force	64 550	50 400	65 000	64 500	65 200	58 300	63 700	60 000	66 000
Heating surfaces, sq. feet :									
Tubes and flues.	4 303	4 069	5 015	4 700	4 656	4 402	4 471	4 860	5 132
Fire-box	395	368	491	493	558	379	446	540	540
Total evaporative	4 698	4 437	5 506	5 193	5 214	4 781	4 917	5 400	5 672
Superheater	1 634	1 327	2 451	1 324	2 357	2 265	2 229	2 403	2 426
Combined	6 332	5 764	7 957	6 517	7 571	7 046	7 146	7 803	8 098
Grate area	69.86	63.0	92.3	88.2	100.0	97.7	88	103.0	108.0
Weights, lb. :									
On drivers	271 000	255 500	260 000	269 000	288 000	247 300	252 000	258 814	272 880
On leading truck	59 000	63 000	62 000	62 500	87 000	78 000	64 000	79 330	65 410
On trailing truck	60 000	59 500	63 000	89 500	123 000	95 600	92 500	112 694	93 950
Engine total.	390 000	378 000	385 000	421 000	498 000	420 900	408 500	450 838	432 240
Tender	378 360	194 000	273 000	216 000	320 000	326 900	269 500	289 162	292 260
Locomotive	758 360	572 000	658 000	637 000	818 000	747 800	678 000	740 000	724 500
Ratios :									
Weight on drivers, % of total	69.4	67.7	67.5	64.1	57.7	58.7	61.7	57.3	63.1
Engine weight ÷ comb. heat. surface.	61.5	65.7	47.2	64.5	65.9	59.8	57.2	57.4	53.3
Adhesive factor.	4.2	5.07	4.0	4.17	4.42	4.24	3.96	4.3	4.13
R.T.F. × diam. of drivers ÷ comb. heating surface	733	647	604	762	655	663	621	567	597
Superheat surface, % of comb. h. s.	25.8	23	30.8	20.3	31.1	32.2	31.2	30.8	30.1
Combined heat. surface ÷ grate area.	79.3	91.5	86.0	73.8	75.7	72.1	81.6	76.4	74.7
Superheater, type.	E	A	E	E	E	E	E	E	E

ches and as much as 30 inches, with, consequently, high piston loads to be transmitted through the motion and framing. In considering this, it must, however, be remembered that the bar type of main frame, when compared with that of plate construction, is particularly well adapted to meet the stresses imposed, and makes it possible to provide an adequate support for the axle-boxes, as the centre of the boxes and the journal bearings can coincide with the centre line of the side members of the main frames. So far as motion parts are concerned, alloy steels are frequently used, and the older strap form of big end for the connecting rods is giving place to a solid end fitted, as a rule, with floating bushes, which are also often applied to the side rod pins.

In order to reduce reciprocating weights, crosshead design is receiving attention, and the Laird type is much used. Another underhung design having multiple bearing surfaces working in a specially formed single slide bar is also common. This construction originated on the Pennsylvania, where it was introduced in the first place for heavy freight engines, its use being now extended to passenger engines of the later « K. 4. s » and new « K. 5 » and « M. 1 » and « M. 1. *a* » classes. This type of crosshead has also been fitted by Baldwin to engines for other lines (3).

On account of the stresses imposed, and the weight to be carried, journal bearings must be of large size, and those for the main axles are always larger than for the other coupled axles. Axles are usually hollow bored, and so are crank pins, the weight being thus reduced; but the practice is especially useful where, as is generally the case, these parts are of heat treated steel. Main driving boxes are now often fitted with supplementary adjustable side bearings, as well as with the usual crown brass.

While the one-piece locomotive bed frame is, possibly, one of the most notable features of modern construction, a further interesting innovation is the growing use of roller bearings, more especially for tender and engine trucks, though experiments are being made now with roller bearings on the coupled axles. Machine friction will be reduced by this form of journal bearing, but reduced maintenance costs and increased availability are the primary considerations.

Tenders.

The large engines now in use naturally require considerable supplies of fuel and water; consequently, large tenders are provided. Fuel space has increased from about 12 tons to as much as 28 or more in certain instances, and in like manner the amount of water carried has risen from 8 000 to over 22 000 gallons, U. S. measures, in both instances. The use of these large tenders has eliminated special stops for re-fuelling and taking water, and has been a factor in enabling the extension of locomotive runs, and has, therefore, played an important part in reducing operating costs.

Examples of very large tenders as applied to fast passenger locomotives are to be found on the New York Central, where those fitted to the *Hudson* class have a loaded weight of 302 700 lb., the fuel carried being 28 tons, 56 000 lb., and the tank capacity 14 000 gallons, whereas the standard *Pacifics* of 1920 had tenders of 168 000 lb. weight, when loaded with 8 000 gallons of water and 12 tons of coal.

On the Pennsylvania the latest K. 5 *Pacifics* have tenders carrying 35 600 lb. of coal and 14 000 gallons of water, and a full weight of 244 900 lb., while the

(3) For a description see *The Engineer*, May 15th, 1925, page 551.

« M. 1. *a* » 4-8-2 engines have tenders turning the scale at no less than 378 360 lb., or 168 long tons, which can carry 63 000 lb. of coal, and 22 000 gallons of water.

The construction of these high-capacity tenders has been greatly facilitated by the development made in the design of the underframing, which now takes the form of a single steel casting, which makes at the same time a bottom for the tank. This has proved a very strong structure, necessary when it is considered that the length between the truck centres may be as much as 32 feet and the total length of the tank 48 feet or more. The tender sides are either riveted to the frames or welded, and often the whole upper part is welded together throughout, which makes a satisfactory construction, being strong and free from leakage; further, a neat finish is readily obtained. Tender trucks are of cast steel, frequently of the six-wheeled type. Rolled steel solid wheels, 33 inches diameter, are practically standard, with journals of about 6 1/2 by 12 inches.

Increase in size and power.

Before describing representative examples of modern high-speed passenger locomotives, which have been selected for treatment, it will be of interest to note the increase in size of engines of this type. Figure 1 shows to the same scale the N.Y.C. engine No. 999, built by Buchanan in 1892 and exhibited at the World's Fair in 1893, and a modern 4-6-4 *Hudson* type locomotive as now in use on the New York Central lines. The 4-4-0 or *American* type engine is superimposed on the 4-6-4, thus bringing out clearly the increase in size that has taken place during the last forty years of development, and it will be noted that the new engine is as large as the entire locomotive of 1892, including the tender. The comparative size of these engines as thus illustrated will be of further interest when reference is made to the next diagram, figure 2, in which the pull, speed, and horse-power are plotted for the 4-4-0 engine, a representative *Pacific* of 1918, and for the 4-6-4 *Hudson* of the present day. The leading dimensions and other data appertaining to these engines are given in Table III.

Referring to the graph, the full lines represent the pull available at the rear of the tenders between 10 and 70 miles per hour, and the broken lines the indicated tractive effort at the cylinders. The D.B.H.P. curves are also shown for the three engines, and for the 4-6-4 the I.H.P. curve is plotted as well. In the lower part of the diagram are shown by the lines sloping upwards to the right the resistance offered by the trains. The upper curve relates to a modern passenger train of 1 000 tons made up of 75-tons coaches, and the lower to the Empire State Express of 1892 made up of 35-ton cars and having a weight of 200 tons behind the tender.

Referring to the tabulated statement, it will be noted that the heating surface per D.B.H.P. at 60 m.p.h. has fallen from 4.03 square feet in 1893 to 2.52 square feet in 1927, the date when the first of the 4-6-4 engines was introduced, and that the locomotive weight per D.B.H.P. developed at 60 m.p.h. has during this period been reduced from 427 lb. to 256 lb. A similar comparison can also be made between the standard *Pacific* of 1918 and the 4-6-4, where it will be seen that although the latter engine has a tender weighing 302 700 lb., as against 194 200 lb. in the case of the *Pacific*, representing an increase of 55 %, the locomotive weight is only 256 lb., as against 247 lb. per D.B.H.P., equal to an increase of 3.5 %.

If we now compare these engines on the basis of engine weight only — that is, comparing the weight of the actual power plant with the D.B.H.P. or net

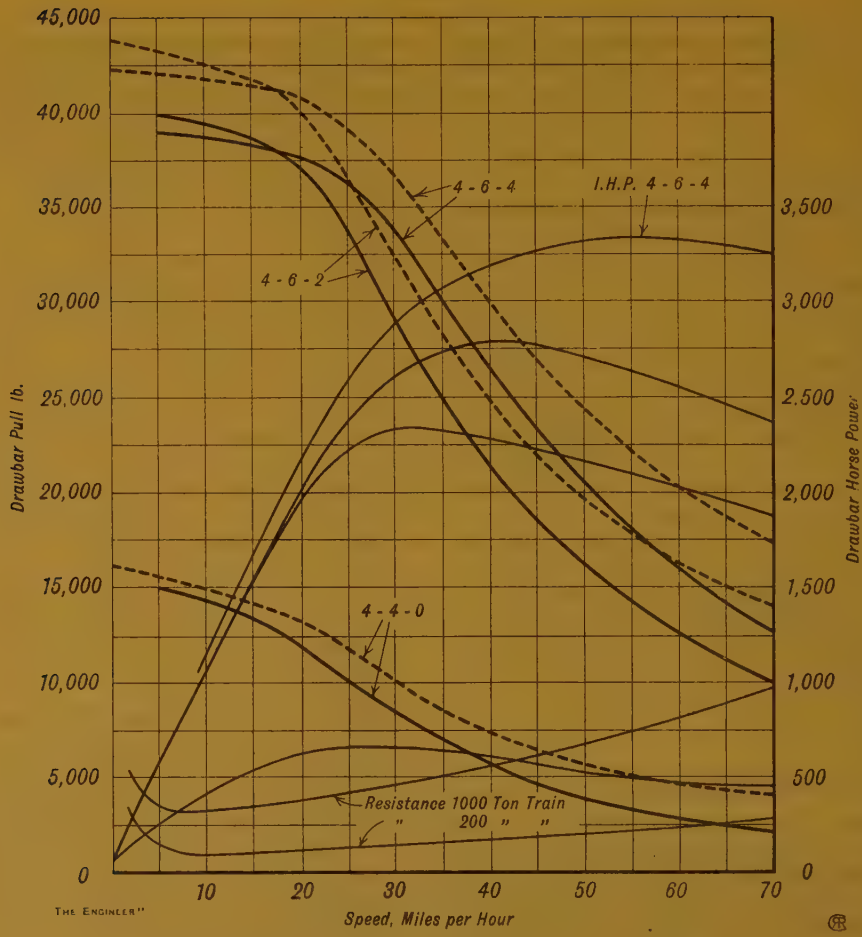


Fig. 2. — Characteristics of 4-4-0, 4-6-2 and 4-6-4 engines.

power available — the following figures are found : —

	4-4-0	4-6-2	4-6-4
Engine weight per D.B.H.P. . . lb.	840	151	138
Weight on drivers per D.B.H.P. . . lb.	176	97.7	73.6

Mention has already been made of the desirability of restricting the weight carried by the driving axles, and in regard to this the improvement made in the power output in relation to the adhesive weight is of interest. Referring to the cylinder power developed per coupled axles, the I.H.P. curve for the 4-6-4 shows that at 60 m.p.h. the indicated horse-power reaches just over 3 300, or more than 1 100 I.H.P. per axle.

The data just discussed show the improvement in the power weight ratio, both in respect to engine weight and to that carried on the driving wheels when the adhesive factors are practically

TABLE III. — **Comparative particulars of express locomotives**

Date	1893.	1918.	1927.
Wheel arrangement	4—4—0	4—6—2	4—6—4
Cylinders, diam. and stroke, inches	19 × 24	27 × 28	25 × 28
Driving wheels, diam., inches	86	79	79
Rated tractive force, lb.	16 200	43 900	42 300
Heating surfaces, sq. feet :			
Evaporative	1 920	3 824	4 484
Superheater	—	887	1 951
Total combined	—	4 711	6 435
Grate area, sq. feet	30.7	70.8	81.5
Boiler working pressure	190	200	225
Weight, lb :			
Engine	124 000	306 000	352 000
On drivers	84 000	197 000	187 000
Tender	80 000	194 200	302 700
Total, locomotive	204 000	500 200	654 700
Superheat, degr. Fahr.	—	200	250
Draw-bar pull at 60 m.p.h., lb.	2 988	12 616	15 997
Draw-bar horse-power at 60 m.p.h.	476	2 020	2 550
Heating surface per D.B.H.P. at 60 m.p.h.	4.03	2.32	2.52
Locomotive weight, lb. per D.B.H.P. at 60 m.p.h.	427	247	256
Engine weight, lb. per sq. fo t total heating surface.	64.5	65.0	54.6
Superheater type	—	A	E
Feed water heater	—	No.	Yes
Tank capacity, gallons, U.S.	3 587	10 000	14 000
Coal, lb.	13 800	32 000	56 000

equal, and the horse-power curves indicate how, for a given rated tractive effort, the actual power available at high speed has been increased. As bearing on this latter point it is interesting to quote from the *Railway Mechanical Engineer*, February, 1933, which made the following statement : « The combination of the large fire-box, the type E superheater, and the four-wheeled trailing truck has converted the locomotive from a machine rated by its starting tractive force to one which is rated by its horse-power capacity », a statement which adequately sums up the ideas underlying modern locomotive design.

Locomotives of the 4-6-2 and 4-6-4 types.

In the foregoing notes the writer has made no attempt to do more than outline the salient features of modern express locomotives, it being only desired to draw attention to certain constructional and other features, and it is now proposed to supplement the remarks already made by offering some descriptive notes relative to recent designs, supported by illustrations. The engines will be mentioned in the order in which they appear in the tables of dimensions. The first locomotive — figure 3 — represents the latest *Pacific* as built by the Baldwin Locomotive Works, for service on the Central Railroad of New Jersey (C.R.R. of. N.J.). Actually, these engines have been built to work fast and medium speed trains when the stops are frequent, and a high tractive effort is required for rapid starting. They follow in general design a number previously placed in traffic, but have smaller wheels, and an increased boiler pressure,

so, though the cylinders are of equal size, the higher rated tractive effort of 52 189 lb. is obtained, compared with 46 841 lb. for those having the larger, 79-inch, wheels. The superheater is of the A type, but is of large size, having forty elements and 1 000 square feet of heating surface, or 27 % of the total combined surface. The fire-box has a combustion chamber, and the distance over the tube plates is 18 feet 8 inches. The 207 tubes are 2 inches and the forty flues 5 3/8 inches diameter. A feed-water heater of the *Elesco* type is fitted, which is, as shown, mounted on the smoke-box in front of the chimney, a position which enables the condensate to drain readily by gravity to the feed connection between the feed pump and the tender. The feed pump is shown fitted to a bracket on the side of the boiler; it is of the Duplex pattern, designed to give a constant feed, thus eliminating hammering of the check valve. This equipment is frequently fitted and is of the closed type, the feed being passed through a series of tubes in the heater, over which the exhaust steam passes, so giving up its heat to the feed water and condensing, as in a surface condenser. Floating bushings are applied to the main and coupling rod pins, and the 13-inch piston valves receive a 6 1/2-inch maximum travel through a light design of Walschaerts motion, controlled by power reversing gear. The tender carries 13 100 gallons of water, and 15 tons of coal, and has a cast steel water bottom underframe to which the side sheets are welded; all the internal bracing is also welded to the side sheets. A mechanical stoker is provided and three Nicholson syphons are fitted. The trailing truck is of the usual single-axle type, with cast steel framing. This design of truck is roughly triangular in plan and swings from a centre just behind the trailing axle, and the weight is taken at this point and also at the two hind corners under the rear of the fire-box. The springs are overhung and are compensated with those for the trailing coupled axle through compensating beams fulcrumed in the truck frames. In conformity with usual practice, the Westinghouse air brake acts on the coupled wheels and on the tender.

The Baltimore and Ohio (B. and O.) utilise the class of engine shown by the next illustration — figure 4 — to work the more important express trains between Jersey City (New York) and Philadelphia, Washington, St. Louis, and Chicago. These locomotives, known as the « President » type, have been built by Baldwin to meet the requirements of Mr. G. H. Emerson, Chief of Motive Power, and are amongst the most powerful *Pacifics* running, having a tractive effort of 50 000 lb., rendered possible by the high axle loading allowable. The weight on the drivers is 201 000 lb., or 67 000 lb. per axle, equal to 29.9 long tons. The boiler is of the usual radial stayed round top type, and the fire-box has a combustion chamber, and two syphons, whilst two arch tubes support the arch. The length over the tube sheets is 19 feet, and there are 212 2 1/2-inch tubes, and forty 5 1/2 inch flues for the type A superheater. The water spacing round the foundation ring is of ample size, being 6 inches at the front and 5 inches at the sides and back. These engines are fired by a mechanical stoker, the operating engine being on the tender. The connecting-rod big ends have foating bushes, which are also applied to the side rod pins. The main driving axle journals are 12 1/2 by 13 inches and those for the other coupled axles are 11 by 13 inches long. Walschaerts gear operates 14-inch piston valves, having a 7-inch full gear travel, 1 1/8-inch lap, and 1/4-inch inside clearance. A power reversing gear is fitted. A forced feed lubricator supplies oil to the cylinders, valves, stoker engine, and air brake compressor. The tenders have a

Fig. 3 (above). — Central Railroad of New Jersey 4-6-2 type locomotive.
Fig. 4 (centre). — Baltimore and Ohio « President » class 4-6-2 type locomotive.
Fig. 5 (below). — Pennsylvania Railroad class K.5, 4-6-2 type locomotive.

one-piese cast steel underframe and carry 17 1/2 tons of coal, and 11 000 gallons of water; they run on eight wheels, and a water scoop is applied, operated by a 12-inch air cylinder.

It may here be mentioned that the Baltimore and Ohio (B. & O.) the C.R.R. of N.J., the Pennsylvania, and the New York Central, are the only lines using track troughs.

The New York and St. Louis fast trains weigh up to 940 tons, and the New York-Washington expresses to about 526 tons behind the tender, the journey between the latter points of 226 miles being made in 4 h. 45 m. with eight stops.

The principal fast passenger services on the Pennsylvania (P.R.) are handled by engines of the *Pacific* type, the latest example of which is shown by the photograph reproduced in figure 5. This locomotive has been designed and built at Altoona Pa, by Mr. F. W. Hankins, Assistant Vice-president in charge of operation. In general, the design follows closely the *Pacific* Class K. 4.s, first built in 1914 by the late Mr. J. T. Wallis, but some important modifications have been introduced, which bring them into line with modern practice. The boiler in respect to overall dimensions is the same as for the class « K. 4.s » engines, and in

construction also follows Altoona practice; but the material used is now a nickel steel for the barrel, and for the combined throat and bottom half of the rear barrel section. The material has a tensile strength of 75 000 lb., comparing with 60 000 lb. for carbon steel plates. The nickel content is specified to be within the limits of 2.75 to 3.25 %. The minimum ultimate tensile strength is 70 000 lb., and the yield point 0.5 of this figure.

The type A superheater of forty elements originally employed has given place to one of the type E with side headers. There are 170 3 1/2-inch flues, and ninety 2 1/4-inch tubes, the length between the tube plates is 19 feet, as for the earlier engines. The fire-box, with combustion chamber, is as before, and the grate area of 69.89 sq. feet is also retained. The changes made in the superheater and tubes have resulted in an increase in the total heating surface of 18.75 %, but the engine weight is increased by only 3.2 %. A further important modification is the use of a one-piece cast steel engine bed frame, which includes in one unit the framing, with all brackets, the cylinders with valve casings and the saddle. This casting, an illustration of which is reproduced in

Fig. 6. — Cast steel frame, Pennsylvania Railroad class K.5 locomotive.

figure 6, was made by the General Steel Castings Corporation. The cylinders are 27 by 30-inches, and steam distribution is effected by 12-inch piston valves set to give a full gear cut-off of 70 %, and operated by a light design of Walschaerts motion, which is controlled by a power reversing gear. The working steam pressure is 250 lb. per square inch. A feed-water heater is fitted. It is of the Worthington S type. The heater or mixing chamber is placed over the smoke-box behind the chimney, where it can be readily connected to the exhaust passages. Cold water is delivered to the mixing chamber by a rotary pump, driven by a steam turbine assembled complete as a unit, and fixed under the footplate. The hot feed is supplied to the boiler by a horizontal reciprocating pump mounted on the left-hand side of the engine at the front end. There is an automatic control for the feed obtained by slowing down the pump when the throttle is closed or only slightly open, as when « drifting ». The feed water temperatures vary from 210 to 230° F., and higher temperatures are not desired, as the blast pipe and chimney have been specially designed with the idea of reducing back pressure on the pistons. The superheater delivers steam at temperatures of between 700° and 750° F. The motion parts are of light design and the crossheads of the multi-bearing pattern. The main rods have floating bushes at the crank pin ends, and the coupling rod pins are similarly fitted. The trailing truck is of the single-axle type standard on the Pennsylvania, and the weight, instead of being taken at the hind corners and pivot centre, is borne by the

frame side members through combined sliding and spherical bearings abutting on the underside brackets cast on the main frames. The leading end of the truck frame connects through suitable links with the bearing springs for the trailing coupled axle. It will thus be seen that the truck framing serves also as a compensating connection. The spring compensation is continuous from the leading drivers to the trailing truck. The tenders are of novel design especially so far as the under framing is concerned, which is a single steel casting, but without side sills. The draw gear pocket at each end is cast integral, and at the bogie centres side bearer arms project outwards to support the tank, which is strongly braced internally in such a manner as to transfer all strains to the centre member of the frame. The tender, which is fitted with a water scoop, carries 14 000 gallons of water, and 16 tons of coal; it runs on eight wheels and weighs, loaded, 245 000 lb.

The following short tabulation compares the previous « K. 4.s » and the present « K. 5 » locomotives :

Class.	K.4.s	K.5
Cylinders	27×28	27×30
Drivers, diameter, inches	80	80
Steam pressure	205	250
Tractive effort, lb.	44 460	54 675
Total heating surface, sq. feet	4 984	5 919
Grate area, sq. feet	69.18	69.89
Weight on drivers, lb.	201 830	207 600
Weight of engine	308 890	318.700

The New York Central (N.Y.C.) employs 4-6-4 engines of the *Hudson* type for working all important express services, and as this design has already been fully described by the writer in *The Engineer*, extended reference will be unnecessary (4).

The illustration figure 7 shows one of the latest of these locomotives to be put into traffic, which, like the others, has been built by the American Locomotive Company. This particular engine, No. 5344, is of interest, because it is equipped with Timkin roller bearings on the leading truck journals, the coupled axles and the tender trucks. The trailing four-wheeled truck has ordinary bearings. An exactly similar locomotive, No. 5343, is fitted in the same manner with S.K.F. bearings. Both were put into service late in 1931, and up to January 1st, 1933 No. 5344 had run 158 300 miles, and 5343 had covered 160 700 miles with satisfactory results. The trains hauled by engines of this type are amongst the heaviest and fastest in the country, and on many of the services, the length of individual engine runs has been much extended. In this connection it will be of interest to note that the 20th Century Limited, running between New York and Chicago, a distance of 962 miles, is now operated by two engines only, compared with seven required in 1918. The steam locomotive replaces the electric at Harmon, 33 miles out of New York, and works through to Cleveland, 588 miles, where a change is made, the second engine running the remaining 341 miles to Chicago. The load to-day is fifteen Pullmans, as against ten in 1918.

The Chicago, Milwaukee, St. Paul and Pacific (C.M. and St. P.) engine next

(4) *The Engineer*, November 16th, 23rd, and 30th, 1928.

See also *Bullletin of the Railway Congress :* February 1926, p. 130; June 1927, p. 552; July 1930, p. 1699; May 1931, p. 380; October 1933, p. 941.

Fig. 7 (above). — New York Central « Hudson » type 4-6-4 locomotive.
Fig. 8 (below). — Chicago, Milwaukee, St. Paul and Pacific 4-6-4 type locomotive.

illustrated — figure 8 — represents one of fourteen passenger engines built by Baldwin and completed in 1930. From the particulars given in the table it will be gathered that these locomotives are of considerable power. In respect to boiler capacity they resemble the New York Central *Hudsons*, but the tractive effort is rather greater, the cylinders being 1 inch larger in diameter. The fire-box is fitted with a combustion chamber and there are three syphons, two in the box and one in the chamber. There are 182 3 1/2-inch flues for the E type superheater, and fifty-eight 2 1/4-inch tubes, and over the tube sheets the length is 19 feet. A mechanical stoker is provided. Boiler feed is taken through a Coffin feed-water heater, the heater portion of which is fitted into the upper part of the smoke-box just ahead of the chimney. These locomotives have a one-piece cast steel frame, complete with cylinders and saddle. Roller bearings are applied to the wheels for the trailing truck. The Baker gear operates 14-inch piston valves and reversal is by means of a power control. The revolving, and 50 % of the reciprocating, weights are balanced. The tender runs on twelve wheels, and carries 20 tons of coal and 15 000 gallons of water. The air brake acts on the tender; the air pressure is furnished by an 8 1/2-inch cross-compound compressor.

The Boston and Albany (B. and A.) 4-6-4 engines mentioned in the table are generally similar to the *Hudsons* of the N.Y.C., of which system the B. and A. is part. They differ in having smaller drivers and in respect to the working steam pressure, which is 250 lb. per square inch. The full gear cut-off is 65 %.

4-8-2 and 4-8-4 types locomotives.

In considering now engines of the eight-coupled type, the first example

given in table II, represents the latest *Mountain* type, introduced by the Pennsylvania in 1930. Actually the design is a development of an experimental 4-8-2 built for test purposes at Altoona in 1923. It may be interesting to note briefly the evolution of this type of engine on the Pennsylvania. Prior to the building of the 4-8-2 type, all important trains were handled by the K.4.s. *Pacifics* or the E.6.s. *Atlantics*, but heavier trains and the difficult road between Altoona and Pittsburgh, between which points the line crosses the Alleghenies, demanded engines of much greater power. Accordingly a large 4-8-2 was designed in 1923. This engine, with 37-inch by 30-inch cylinders, 72-inch wheels, and 250-lb. boiler pressure, represented a great advance in power over the existing engines mentioned, as it had a rated tractive effort of 64 500 lb. The boiler had a type E superheater and a total heating surface of 6 704 sq. feet with a grate area of 70 sq. feet, and weighed, engine only, 384 300 lb. A number of trials were made with this engine, both on the plant and on the road, and experience showed

Fig. 9 (above). — Pennsylvania Railroad class M. 1, 4-8-2 type locomotive, 1926.
Fig. 10 (below). — Pennsylvania Railroad class M. 1. a, 4-8-2 type locomotive, 1930.

that at high powers the steam volume given by the boiler was deficient. Alterations in the boiler diameter were made, and with good results, and a revised design of generally the same dimensions appeared in 1926. This engine, which is illustrated in figure 9, is, like the original, classified M.1. The boiler is remarkable for the very large fire-box and combustion chamber, the latter being 8 ft. 2 in. long, and in consequence the tube length is only 19 feet, which is short for an eight-coupled engine. This arrangement was used also for the trial engine. The cylinders, wheels, and steam pressure are as before, but instead of being hand-fired a stoker is fitted. During 1926 and 1927 the Pennsylvania placed 200 of these locomotives in fast passenger and freight traffic. They were built by Baldwin and by the Lima Locomotive Works. Their success led to the design being developed further, and in 1930 those of

the class M.1.a., as next shown — figure 10 — were built. The dimensions given in table II relate to the M.1.a. class, but are applicable to the previous M.1., except for the weights and data relative to the tenders which are much longer for the newer locomotives. In construction, the M.1.a. class differ in having a one-piece cylinder casting in steel, with a saddle, which, as in the case of the K.5 *Pacifics*, is long enough to constitute practically the bottom of the smoke-box. A further change of importance is the inclusion of a feed-water heater; the type used is the Worthington S pattern, of very large capacity, capable of supplying 62 108 lb. of water per hour. The tender is of exceptional size, with a 22 000-gallon tank and space for 63 000 lb. of coal. A scoop is provided.

As was the case with the two previous designs, one of these engines has been tested on the Altoona plant and shown a very high capacity. When working all out the indicated horse-power developed was 4 662 and at the draw-bar 4 034. This power output was attained at 240 r.p.m. and 65 % cut-off. The boiler showed an equivalent evaporation of 113 368 lb. per hour, or an actual of 92 084 lb. The dry coal fired per hour was 21 271 lb. and the steam pressure maintained averaged 241 lb. per square inch delivered at a total temperature of 733° F.

The Baltimore and Ohio (B. and O.) engine — figure 11 — has been built by Baldwin to the requirements of Mr. Emerson. The design is experimental, being specially worked out to comply with severe weight and clearance limitations, whilst, at the same time, developing high power for operation in heavy passenger services. It will be noted that the engine is very light in comparison with the heating surface provided. The cylinders are 27 1/2 by 30 inches, and the piston valves have a diameter of 12 inches and a full gear travel of 7 inches when the cut-off is 87 %. As will be seen, Walschaerts gear is used. The superheater is of the E type, and two Nicholson syphons are fitted in the fire-box. Other equipment includes cast steel cylinders, Sellars exhaust steam injector, power reverse gear, and a

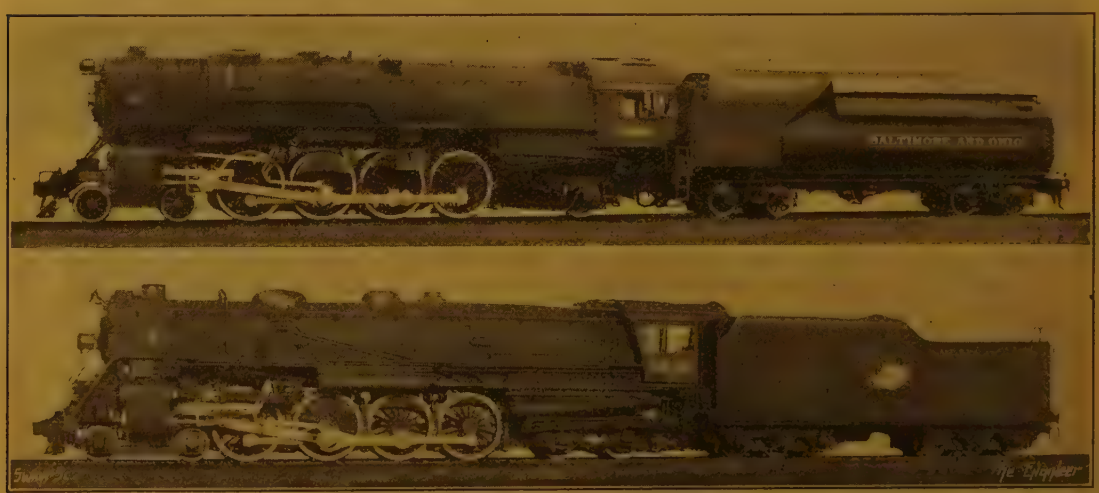


Fig. 11 (above). — Baltimore and Ohio 4-8-2 type locomotive.
Fig. 12 (below). — Chicago and North Western 4-8-4 type locomotive.

mechanical stoker of the Lower pattern. The length between the tube plates is 21 feet, and there are fifty-nine 2 1/4-inch tubes, and 224 3 1/2-inch flues. The superheating surface is 2 451 sq. feet, or 30.8 % of the combined total of 7 957 sq. feet. All the motion parts have been carefully proportioned to save weight, and the same remark applies to the frame construction, which is of the normal type, but the cross stretchers are welded to the side members, thus eliminating to a large extent bolts in the building of the frame structure. The tender is of the Vanderbilt design, and runs on two four-wheeled trucks. It carries 18 000 gallons of water and 20 tons of coal, and has a loaded weight of 273 000 lb., and is light for the carrying capacity. A further engine of the same general design is also in traffic, but having an Emerson water-tube firebox and type A superheater.

The dimensions of a large locomotive having the 4-8-4 wheel classification is given by the next example in the table. Five were built in 1927 by the American Locomotive Co. for the Delaware, Lackawanna and Western (D.L. and W.) for fast passenger service, principally between Hoboken, N. J., and Scranton, Pa. These engines are remarquable for the large size of their coupled wheels, and the high tractive effort of 64 500 lb. The 77-inch drivers were, when the engines were built, the largest found in an eight-coupled design. The line between Hoboken and Scranton crosses the Pocono Mountains over steep gradients, both east and west-bound, but on the more favourable sections of the run some high speeds are required; hence the large-diameter driving wheels. These engines are stoker fired, and provision is made for the application of a booster to the rear axle of the trailing engine truck if required.

The Baldwin Locomotive Works built the Chicago and North-Western (C. and N.W.) engines represented by figure 12, which are amongst the largest passenger engines so far built. The tractive effort with the normal boiler pressure of 250 lb. per sq. inch is 65 200 lb., or, with the trailing truck booster, 76 500 lb., but if the pressure is raised to 275 lb. per sq. inch, for which provision is made, the tractive effort will be 71 800 lb. and 84 200 lb. respectively.

The locomotives are fitted with type E superheaters, Worthington S type feed heaters, three syphons, two in the firebox and one in the combustion chamber, a modified B type stoker, and a tangential steam separator which is fitted to the steam pipe in the dome. The main throttle is of the multiple-valve pattern, housed in the superheater header. A notable feature is the one-piece cast steel underframe, which includes the cylinders and saddle, and the absence of outside steam pipes will be noted, their place being taken by cored passages in the saddle. The frame casting is 58 ft. 3 in. total length, and has a weight of 72 000 lb. The boiler has a largest diameter of 100 inches outside,where the plates have a thickness of 1 3/16 inches. There are fifty-one 2-inch tubes, and 214 3 1/2-inch flues, and over the tube sheets the length is 21 feet. The 27-inch by 32-inch cylinders have 14-inch piston valves, and five engines have Baker gear, and thirty Walschaerts. Power reversing gear is fitted. The main connecting-rods are of the Woodard or articulated design, a construction which relieves the main pins of part of the piston thrust, and dispenses with the usual knuckle-pin arrangement in the side rods. The main and intermediate journal boxes have brasses of the adjustable three-piece type, and the bearings are 13 1/2 by 14 inches for the main, and 12 by 14 inches for the others. Of the thirty-five locomotives, twenty-five have tender trucks fitted with the American Steel Foundries roller bearing units, and all the tenders have cast steel water bottom underframes, as illustrated by figure 13.

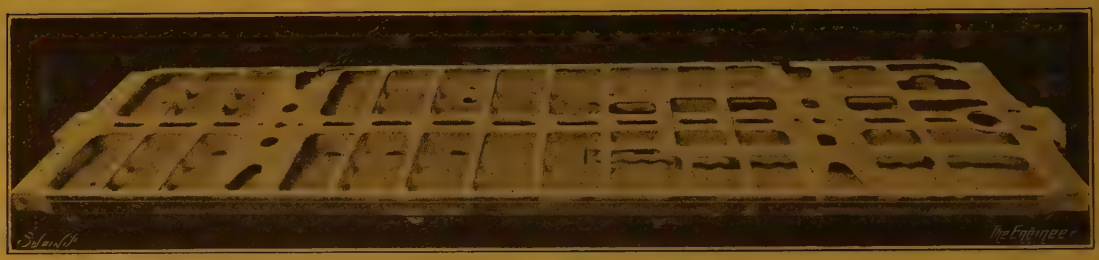


Fig. 13. — Cast steel water bottom tender frame, Chicago and North Western, 4-8-4.

The tank capacity is 18 000 gallons, and the fuel space is sufficient for 20 tons of coal, and, when thus loaded, the tender weight is 320 000 lb. Referring to the feed heater, it may be mentioned that the hot-water pump of the reciprocating pattern is seen arranged over the right-hand cylinder valve casing. The heater itself is just in front of the chimney. The sloping of the front of the cab is becoming common practice, as it materially adds to accessibility for the examination of the fire-box stay bolts.

As already pointed out, these locomotives are amongst the largest so far built for passenger service, and a few of the more important dimensions which will give an idea of their size are given as under :

Height to top of chimney from rail	15 ft. 11 3/32 in.
Height from rail to boiler centre.	10 ft. 8 in.
Driving axle wheel base .	20 ft. 6 in.
Rigid wheel base . . .	13 ft. 4 in.
Wheel base, engine. . .	48 ft. 7 in.
Wheel base, locomotive .	91 ft. 1 in.
Total length over couplers	103 ft. 4 in.

Early in 1930 the Baldwin Locomotive Works delivered fourteen large 4-8-4 engines to the Great Northern (G. N.) for operating passenger trains on the more level sections of the line, and one is illustrated by figure 14. These locomotives, the leading dimensions of which are given in table II, are remarkable for the large size of the coupled wheels, which have a diameter of 80 inches, the largest applied to an eight-coupled design. The boiler is of nickel steel, and has a large fire-box with combustion chamber, a type E superheater, and is fed by an exhaust steam injector. There are 195 3 1/2-inch flues, and thirty-eight 2 1/4-inch tubes, and the length over the tube sheets is 22 feet. The frames are of the normal cast steel bar type, and the cylinders are also of cast steel. Walschaerts' motion imparts a 7 1/2-inch full gear travel to the 14-inch piston valves, and a power reverse gear is fitted. The working steam pressure is 225 lb. per sq. inch, and four valves are used; they are loaded to blow off at 225 lb., 226 lb., 227 lb., and 228 lb. respectively. The two 8 1/2-inch cross-compound air compressors for the brake are mounted on the smoke-box front and use superheated steam. A multiple-valve throttle is fitted. The leading truck has outside journal boxes, and is of a special design developed by the builders, having a one-piece framing of cast steel; the two side frames are connected to each other front and back, thus enclosing the wheels, and these end sections are braced to the centre by longitudinal stiffening members. The spring gear is equalised and the centering rockers are of the constant-resistance type. The leading truck wheels are 36 inches, and those of the trailing trucks of equal size are 45 inches diameter. A tender of the Vanderbilt design is used, the body of which is welded throughout. It is mounted on a Common-

Fig. 14 (above). — Great Northern 4-8-4 type locomotive.
Fig. 15 (below). — Denver and Rio Grande Western 4-8-4 type locomotive.

wealth cast steel frame of the water bottom design. The six-wheeled trucks have cast steel frames. These locomotives use oil fuel, and there is tank capacity for 5 800 gallons of oil and 17 000 gallons of water.

For working heavy passenger traffic over a very difficult road, the Denver and Rio Grande Western (D. and R.G.W.) utilise the class of engine shown by figure 15, built to the dimensions given in the table by the Baldwin Works. These engines are equipped with feed-water heaters, type E superheaters, Nicholson thermal syphons, power reversing gear, and cast steel cylinders. The valves, of the piston type, have a diameter of 14 inches, and are operated by Walschaerts motion, modified to provide variable lead which is increased as the gear is linked up. The arrangement is interesting, and is as follows. The upper end of the combining lever is slotted out to receive a die block fitted with a pin, which also passes through the forked end of the radius rod, which connects with the die in the expansion link. The pin engaging the radius link at the combining lever end is also long enough to engage with a short lifting link connecting with the horizontal arm of a bell-crank lever, the vertical member of which is, in turn, connected by a rod with an arm on the main reversing shaft. When the motion is in the mid-gear position, the arm on the reversing shaft, which is at 180° with the lever operating the lifting links for the radius rod, has pushed the vertical member of the bell crank over slightly, and so raised the die block in the slotted end of the combining link, thus increasing the distance between the radius rod pin and the valve spindle centre, thereby adding to the lap and lead movement. The lead is, therefore, increased, but as the lever on the reversing shaft is opposite that controlling the lifting links, it follows that when the motion is put over into or towards either full forward or full back gear, the upper arm of the bell crank is depressed and the die in the combining lever, therefore, brought nearer to the valve spindle centre, thus reducing the lead opening. The bell crank and its connection with the die in the combina-

tion lever can just be made out in the illustration of the engine. The lead is zero in full gear, and increases to 3/8 inch at 25 % cut-off.

The boiler is of the usual round-top, radial-stayed description. It carries a pressure of 240 lb. per sq. inch, and has a fire-box fitted with a combustion chamber, and the grate has an area of 88 sq. feet. A mechanical stoker is provided. There are 195 3 1/2-inch flues, and forty-three 2 1/4-inch tubes, and the length over the tube sheets is 22 feet. The main journal bearings are 13 by 14 3/4 inches, and those for the other coupled axles are 11 1/2 by 14 3/4 inches. For the leading truck the wheels are 36 inches diameter, with journals 7 by 14 inches, and for the four-wheeled trailer the wheels are 42 inches with journals 9 by 16 inches. Two 8 1/2-inch cross-compound compressors are fitted and the air brake acts on all the coupled and the tender wheels. The tender, which runs on six wheels, carries 29 tons of coal, and has tank capacity for 14 000 gallons of water. The wheels are 36 inches diameter, and the journals measure 6 by 11 inches. These engines operate over the main line extending from Denver, Col., to Ogden, Utah, a distance of 782 miles, traversing the Rocky Mountain district, and crossing the Continental Divide at Tennessee Pass, 280 miles from Denver, at an elevation of 10 239 feet. From the east the gradients are 1.42 %, and from the west the maximum gradient is 3 %. The track is laid with 100-lb. and 110-lb. rails.

The next example of the 4-8-4 type is one for the Chicago, Milwaukee, St. Paul and Pacific (C.M. and St. P.), built by Baldwin in 1930 — figure 16. The engine, in many respects, is similar to the *Pacifics*, the main dimensions of which are given in table I, and certain details, where practicable, are interchangeable. The engine has roller bearings for the front and hind trucks, and is replete with a feedwater heater, E type superheater, three Nicholson syphons, and stoker. The unit cast steel framing has the cylinders cast integral, and the *Pacifics* have the same type of frame construction. Laird type cross-heads are common to both designs, and the valve gear is the same type, and arranged in the same manner. The boiler is of considerable size, and is fitted with a combustion chamber in conjunction with a fire-box of ample proportions, having the large grate area of 103 sq. feet. There are 218 flues, 3 1/2 inches diameter, and fifty-six 2 1/4-inch tubes, and over the tube plates the length is 21 feet. The boiler demand factor of 567 indicates considerable steaming power, relative to the horse-power capacity of the cylinders. The piston valves are 14 inches in diameter. The tender carries 20 tons of coal and 15 000 gallons of water, and has roller bearings for the axles.

Both the C.M. and St. P. *Pacific* and *Modified Mountain* type locomotives are fitted with the Coffin feed-water heater, and the same is used also for the later *Hudson* type 4-6-4 engines of the N.Y.C. A short description of this heater will be of interest. The Coffin heater is of the closed type, and consists essentially of the heater and the feed pump units, both separate. The heater is semi-circular in shape, its radius being made to conform to the individual smoke-box to which it is applied. It is usually built into the upper part of the smoke-box, just ahead of the chimney, or it may be mounted outside at the front; but, owing to its shape, it is flush with the top of the box in either case. The semi-circular form allows of the tubes being fixed in rigid tube sheets as their curved shape naturally allows for expansion. The tubes are of copper. The water takes five passes through the heater, the first being farthest from the steam inlet, and the last directly next to the steam baffle. An auxiliary open heater is fitted in the tender. Its function is to combine the

Fig. 16 (above). — Chicago, Milwaukee, St. Paul and Pacific 4-8-4 type locomotive.
Fig. 17 (below). — Atchison, Topeka and Santa Fe 4-8-4 type locomotive.

condensate with the feed water, and liberate dissolved oxygen. The pump is of the centrifugal pattern, turbine-driven by direct-coupling. It is placed below the tank level and usually mounted at the hind end of the engine under the footplate at one side where it is accessible for attention.

The Atchison, Topeka and Santa Fe (A.T. and S.F.) locomotive illustrated by figure 17 is probably the largest of its type for passenger service. The engine frame construction differs from that employed for any of the other engines described, in that the cylinders and valve chests are cast in one piece together with the saddle, and bolted and keyed to a one-piece cast steel bed frame. The cylinders are also of cast steel and special care has been taken with the form of the exhaust passages which are cored in the cylinder casting. It is claimed that, compared with cast iron, the use of cast steel for cylinders saves 25 % in weight. All the coupled axles are hollow bored and so are the main crank pins. The big ends have floating bushings and the crossheads are of the Laird pattern. All the revolving and 50 % of the reciprocating weights are balanced. The writer believes that this proportion of balance for reciprocating parts is usual American practice. The piston valves actuated by Walschaerts motion have a diameter of 15 inches and the long full gear travel of 9 inches when the cut-off is 85 %. The long valve travel is responsible for the inclusion in the valve gear of a novel means for overcoming unfavourable angles in the motion parts. This device, which magnifies the motion imparted to the valve for a given swing of the expansion link, consists of a short lever rocking about a fulcrum fixed in the outer end of the valve spindle crosshead slides. This lever moves in the vertical plane and is linked at is upper extremity to the combination lever, while at a point between this and the fulcrum, connection is made with the radius rod, which has the effect of increasing the valve travel obtainable for any given position of the die in the expansion link, thus maintaining a normal swing and avoiding unfavourable angularity between the link and the excentric rod. A power reverse gear is

applied and provision is made for fine adjustment of cut-off by fitting a reverse gear quadrant with more teeth than usual. The boiler is of the radial stayed type and has a type E superheater, with header fitted with a multiple-valve throttle valve. The blast pipe is very low in the smoke-box, and has a ported nozzle of the Layden type, designed for a large-diameter chimney. The tubes are fifty-seven in number and of 2 1/4-inch diameter, and there are 231 3 1/2-inch flues. The length over the tube sheets is 21 feet. The tender carries 20 tons of fuel and 15 000 gallons of water, the weight loaded being 292 260 lb. There are twelve wheels, having a diameter of 33 inches, and the axle journals are 6 by 11 inches. The air brake acts on the coupled wheels of the engine and also on the tender wheels. These locomotives operate between La Juanita, Col., and Winslow, Arizona, 636 1/2 miles, and between the latter point and Clovis, N.M., 503.5 miles, the last section being a mountain division. The mean speeds vary from 35 to 39 m.p.h. The trains are made up of nine to sixteen cars, equal to 793 and 1 120 tons, and the engines make these division runs unchanged.

Referring to the tables of dimensions, it should be pointed out that the heating surfaces of the fire-boxes in all cases includes that contributed by the combustion chamber and also, where fitted, the syphons and the fire-brick arch tubes. Weight, when given in tons, refers to tons of 2 000 lb., and water capacities are all given in U.S. gallons.

CONCLUSION.

In presenting this review of recent design of express passenger locomotives as used in the United States no attempt has been made to go far into the details of construction, it being the writer's aim to give a general survey of the modern tendencies of design and to mention some notes on the fittings now included in American practice.

The information given and the various photographic illustrations have been collected with the assistance of the various builders, viz., the American Locomotive Company and the Baldwin Locomotive Works, and, in addition, the writer is much indebted to Mr. P. W. Kiefer, chief engineer of motive power and rolling stock, New York Central; Mr. G. H. Emerson, superintendent of motive power, Baltimore and Ohio; and Mr. F. W. Hankins, assistant vice-president, operation, Pennsylvania Railroad; and the General Steel Castings Corporation.

[621.335 (.73) & 621.43 (.73)]

Burlington « Zephyr » completed at Budd Plant.

First Diesel-propelled articulated train of stainless-steel construction for high-speed service.

(From Railway Age.)

Foreword.

The loss of railway passenger traffic during the last decade has been caused by a shifting of travel from the railways to the highway and not from a decline in total travel. In fact, the total passenger one-mile units of travel have greatly increased, but the percentage of the total which has been handled by the railways has been greatly diminished and only twenty per cent as much local traffic by rail was performed in 1933 as in 1920.

Conventional lines have been followed in

the design of passenger equipment for a great many years. In departing from convention and undertaking to make improvements that would result in lower train operating costs with added travel comfort, our idea has been to call upon the industry which has taken from us much of our traffic, namely, the automobile industry.

We have accordingly collaborated with the Edward G. Budd Manufacturing Company, the General Motors Corporation and the Massachusetts Institute of Technology, and with two architectural firms, Paul Cret and Holabird & Root. These concerns were given carte blanche in designing and decorating the Zephyr without any restrictions except those which are inherent to railway equipment, namely, the gage of the track and the clearances within which the outside dimensions must be kept.

The railways are very jealous of their record of safety, and stress was laid in our instructions that no compromise be made with safety but that insofar as possible the safety factors must be increased.

In the consideration of material, the character of which must provide the greatest strength with a minimum of weight, it was of paramount importance that we select a material not only uniform in structure, but one entirely non-corrosive to the end that the section which we rely upon and design for may be permanent during the entire service life of the train.

RALPH BUDD.

* * *

A self-propelled, three-car, articulated high-speed train of light-weight stainless steel construction has been completed for the Chicago, Burlington and Quincy by the Edward G. Budd Manufacturing Company, Philadelphia, Pa. This train, which is known as the « Zephyr » received its first introduction to the public at the Broad Street Station of the Pennsylvania Railroad in that city. It will be placed in service between Kansas City, Mo., Omaha, Nebr., and Lincoln, replacing existing steam service with much faster schedules and, it is anticipated, with a considerable reduction in operating cost.

The train is driven by a Winton 600-HP. Diesel-electric power plant and is designed for speeds of approximately 110 m.p.h. This involved considerations of aerodynamics in shaping the train to reduce the air resistance, both head-end and frictional. Wind-tunnel tests of scale models at the Massachusetts Institute of Technology indicate that at an operating speed of 95 m.p.h. the total resistance to motion will have been reduced to about 47 % of that of a train of three coaches of conventional shape, weight being equal.

But in the development of the train attention was not confined to advanced engineering features. The architectural firms of Paul Cret, of Philadelphia, Pa., and Holabird and Root, of Chicago, collaborated in working out the arrangement, ornamentation and decoration of the passenger accommodations and in the design of the furnishings in order that the train may provide the utmost in comfort and attractiveness to the traveler.

The train consists of three car bodies carried on four trucks. It is 196 feet in length and it is estimated to weigh 195 000 lb. There are seats for 72 passengers in the second and third cars and space is provided in the first and second cars for 50 000 lb. of baggage and express. The first car also contains a 30-foot mail compartment. The passenger accommodations are divided among three compartments. At the rear end of the second car is a 16-foot smoking compartment with seats for 20 persons. At the front of the third car is a 31-foot compartment with seats for 40 persons, and at the rear of this car is a solarium-lounge with chairs for 12. Side doors and steps are provided for passengers in the two rear cars. In the second car the entrance is between the

Fig. 1. — The Burlington « Zephyr » is built of stainless

smoking compartment and the buffet adjoining the baggage compartment. In the rear car the entrance is at the rear of the main passenger compartment.

Fig. 2. — A solarium-lounge is at the rear end of the train.

The car body structure.

In its structure this train is a complete departure from conventional design. To a very large extent the entire body structure from floor to roof performs load-carrying functions. The characteristic truss form of construction adapted by the Budd Company for the utilization of built-up sections of thin-gage Shotweld stainless steel is used. The main members of the car bodies are the Pratt truss side frames which have, in effect, been carried up to the roof by the use of diagonals in wide deadlights between the windows and of which the roof forms the top chord. The truss members are generally of flanged box sections formed of deep flanged channels and cover plates joined by Shotwelds. The steel of which these sections are formed has a minimum tensile strength of 150 000 lb. per sq. inch and an elastic limit of 120 000 lb. per sq. inch, with satisfactory ductility.

A section originally 14 inches in length was tested to destruction in compression and reduced to a length of 6 3/4 inches without a break in the material. This member, of material 0.050 inch thick, has a sectional area of 0.51 sq. inch and weighs 1.77 lb. per lineal foot. Its moment of inertia is 0.35 inch^4 about either axis, and its radius of gyration is

steel and driven by a 600-H.P., two-cycle Diesel engine.

0.8 inch. It withstood under compression 36 000 lb., or over 70 000 lb. per sq. inch. After failure had started the load required to continue the destruction varied up to a maximum of 28 000 lb. As an indication of the weight efficiency, a structural-steel T-section, with the same moment of inertia about its most effective axis, weighs 3.56 lb. per foot, and to secure the same moment of inertia about the least effective axis would require a section weighing 6.4 lb. per foot. A T-section with a least radius of gyration of approximately 0.8 inch weighs 10.5 lb. per foot. The section tested to destruction, owing to the varying nature of the imposed loads, has the least efficiency of any of those used in the structure. Others carry not less than 100 000 lb. per sq. inch under similar tests.

The welding process used was the Shotweld, developed and patented by the Edward G. Budd Manufacturing Company, and which effects a specific regulation of the pressure, the electric current value and the duration of its flow, thus maintaining unimpaired the strength and corrosion-resisting properties of the material. The welds develop a shearing strength of 75 000 lb. per sq. inch and will withstand torsion up to 90° before rupture. All welding in the structure of the Burlington train was done by this process.

The floor structure is made up of a corrugated sheet of stainless steel, the bottoms of the rectangular corrugations

Fig. 3. — Front end of the « Zephyr ».

of which are welded to a flat sheet and both in turn welded to the longitudinal stringers, of which there are eleven across the car. These, in turn, are secured to transverse supports built into the car frame. The floor thus forms a stiff horizontal girder through which end loads are distributed to the side girders. In the baggage compartments it is designed for a loading of 600 lb. per lineal foot.

The roof constitutes a primary structural member assuming the entire compression load. It is built up of longitudinal corrugated sheets welded to roof carlines and is locally reinforced at points of maximum stress. The roof-sheet corrugations are 7/16 inch deep, with a pitch of 1 1/2 inches.

Fig. 4. — Front-end frame structure showing the welded engine bed.

In cross-section the car assumes something of a tubular form. The enclosure below the floor, however, is of only incidental value as a part of the load-carrying structure and the trussed center sills are designed primarily to serve as means of attachment for apparatus, to stabilize the floor beams and to serve as local reinforcement.

Among the special features in the structure which are of particular interest are the engine bed and the method of tying the articulation castings into the framing of the coach bodies. The engine bed, fabricated by Lukenweld, Inc., is a rigid arc-welded structure of steel plate, annealed after completion of the welding. It forms a combination bumper, engine bed and bolster and is 25 ft. 3 1/2 in. long, by 8 ft. 8 in. wide. The material is Lukens Steel Company Cromansil, an alloy of chromium, manganese and silica, with a tensile strength of 90 000 lb. and an elastic limit of 70 000 lb., possessing a high resistance to fatigue and shock. The completed structure weighs 6 070 lb. It is built into the lower chord member of the side trusses and forms the foundation for the nose structure of the car.

The nose construction consists of a deep, stiff member which extends diagonally outward and downward on the longitudinal center plane of the car from the roof to the bumper portion of the engine bed. This is reinforced with a stiff horizontal arch at the belt rail and with a diaphragm which forms the bottom of the engine-cooling air-intake chamber above the cab windows. The diaphragm is composed of two 0.109-inch stainless-steel sheets welded together and reinforced with stiffeners.

Each articulation casting is tied into the frame structure at the end of the car by riveting to the center sills, to the end posts and to the lower chords and vertical members of the stainless-steel end trusses. No rivets other than these are used in the structure. The transverse horizontal arms of the castings extend out only far enough to carry the side bearings, and the load is carried to the side frames through the end truss structure with a considerable saving in weight. Through the stiff end structure the reaction from the weight on the truck center plate is carried to the main side frames. The greater part of the bending moment due to the eccentric loading at the center pin is resisted by compression loading

in the roof and the remainder by a bending stress in the center sills. The end posts are built-up of 1/8-inch stainless-steel plates and are 12 inches deep.

Unlike the stainless-steel cars previously built by the Budd company, the sheathing on the Burlington train is not all of the fluted type adopted to prevent the formation of shear lines and other weaves which would develop in the 0.020-inch sheets. Uncorrugated sheets of stainless steel are used around the curved surfaces at the front and rear ends of the train, on the curved roof at the rear end, and on the roof over the engine room. Except on the front end, where plates are 1/8 inch thick, the material is 0.030 inch in thickness.

The deadlight panels are also finished with smooth surfaces. These panels are of Plymetl, in which the outside surface of the plywood is covered with stainless steel and the inside with copper to prevent warping. These panels, some of which are of unusual length, are flexibly mounted in channels at the top and bottom, in which they are sealed with a plastic calking material. Below the window rail are mounted the customary fluted side sheets.

The space below the floor level is enclosed with light corrugated sheathing similar to the roofing. To prevent resonance from air-borne noises and direct concussions this sheathing is insulated with hair felt placed between two layers of 80-lb. Craft paper, the outer of which is cemented to the sheathing.

The walls and roofs of the cars are insulated throughout with Alfol. This material, which is made up of several sheets of crinkled aluminum foil, weighs about 1/4 ounce per foot, board measure. It combines low conductivity with low convection air spaces and high reflectivity.

In the passenger compartments the side walls are finished with Masonite panels. The headlining is of Agasote. The walls of the baggage rooms are finished with galvanized sheets. The floors are laid with 5/16-inch cork tiling cemented over the corrugated steel and cork filler in the recesses of the corrugations. In the mail compartment 1-inch maple flooring is laid over the cork. In the baggage compartment a layer of roofing paper is placed between the cork and the maple flooring.

All doors, when closed, form unbroken surfaces with the outside sheathing of the car. The doors serving the passenger compartments are of the swinging type and give access to step-wells in the floor which are closed by trap doors. The bottom step folds up when the door is closed and, together, they form an unbroken surface with the undersheathing adjoining the step wells. The side doors in the two baggage compartments and in the railway post-office are of the sliding type. They are guided in top and bottom tracks so shaped as to move the door outwards into its flush position in the door opening when it is closed.

Vestibule passages between the car bodies are enclosed by diaphragms bolted to the ends of the cars. The foot plate is formed by an approximately semi-circular plate, its straight edge secured to the end of one car and the circular edge enclosed in a horizontal recess in the end of the opposite car within which it is free to slide when the cars pass over curved track. To provide continuity of the outer surfaces accordian type diaphragms are attached between the ends of adjoining cars.

The safety window glass supplied by the Pittsburgh Plate Glass Company differs from that ordinarily used. The proposed high speeds of the train and the large area of glass called for increased strength over what would be required in automobile use, but this strength had to be obtained, if possible, without any additional weight. The glass which was finally approved was 15 % lighter than

the standard safety plate glass and much stronger.

Generally speaking, the weight of safety glass is in the glass and the strength is in the plastic sheeting. Therefore, the thickness of the plate glass for this special laminated product was reduced from 7/64 inch to 0.09 inch, and the thickness of the plastic was raised from 0.025 inch to 0.050 inch for the safety glass to be used in the rear and side windows and to 0.075 inch for the safety glass in the front windows. In order to overcome the problem of severe weathering a special plastic sheeting was used which is highly resistant to the ultra-violet sun rays and the glass is developed to almost entirely filter out these rays. With this double protection it is expected that the glass will outlive the train.

Because of the type of construction it was calculated that there would be a certain amount of weaving of the coach bodies which would crack the glass under usual glazing methods. A system was developed of setting it in dum-dum putty, a non-hardening material, which allows play but still hermetically seals the windows to permit the air-conditioning system to operate efficiently. The window sash, furnished by the O. M. Edwards Company, are set flush with the outside surfaces of the train.

The power plant.

The power plant for driving the train, including power auxiliaries, was designed by the Winton Engine Corporation, a subsidiary of the General Motors Corporation. The main generator, exciter, auxiliary generator and traction motors were built by the General Electric Company.

Power for propulsion of the train originates in a Winton 600-H.P. high-compression, two-cycle, 8-inch by 10-inch eight-in-line, Diesel engine. Power for all auxiliaries, whether driven directly or indirectly, is taken from the engine in excess of its rated output of 600 H.P. at 750 r.p.m.

Incorporated in this engine are several novel features of construction and design. For example, engine weight has been reduced to about 22 lb. per H.P. by the Lukenweld process for welding steel plate to form a single-piece engine block, comprising the crankcase and cylinder block, to which a light oil pan is attached. A nine-bearing crankshaft is carried on main bearing seats fastened to the end of individual cross members cut to form frames for the fabricated engine block. In this manner combustion stresses are transmitted directly to the bearing seats, through the solid frames held rigid by the various patterns of welded plate, which incidentally form the air-intake passages, top and bottom of the cylinder block, webbing, etc. Steel-backed, lead-bronze-faced main bearing liners, 6 1/2 inches in diameter, are clamped by shimless bearing caps held in place with jack screws acting against the frame arch below the cylinder block.

Water-jacketed cylinder liners of heat-treated cast iron are bolted to the cylinder heads, which in turn are fastened in the usual manner to the cylinder block. About mid-length are cast twen-

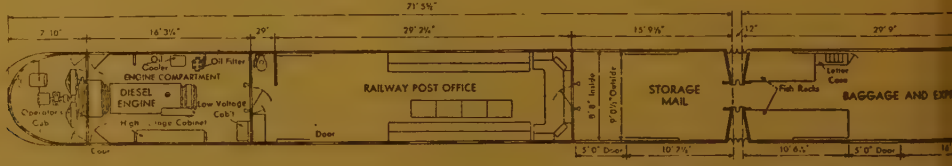


Fig. 5. — Floor plan of th

ty-four oblique air-intake ports circling each cylinder liner. Thus, the cylinder block forms an air-intake manifold in which pressure is maintained by a three-lobed twin-rotor scavenging blower or compressor, mounted on the front end of the engine block. This arrangement of air intake and the use of four exhaust valves per cylinder insures scavenging of the cylinder at a minimum blower pressure. The heads of the aluminum alloy pistons are cooled by a stream of oil emitted from the top of special I-section connecting rods fitted with bearing liners having a 6-inch bore.

The possibilities in power economy, afforded by streamlining railroad equipment, required the remodeling of the conventional engine-cooling and exhaust systems to provide a smooth roof line. To accomplish this the exhaust manifold was lowered into a drop section in the car roof and the customary roof radiators regrouped to form two long sections suspended from the roof inside the engine room. Heretofore, with the roof-type radiators air circulation through the radiators was furnished by the motion of the train, while with the new system of inside mounting an artificial breeze was needed for cooling purposes. Two large engine-driven fans are mounted above the partition separating the engine room from the control cab. A grilled opening in the front of the train admits air to the fans via a duct formed by the cab ceiling and the car roof. The large volume of air brought into the engine room passes through the cooling radiators and thence outside through a central longitudinal slot in the roof. This assures a minimum disturbance of the air stream at the head end of the train and insures a thoroughly ventilated engine room.

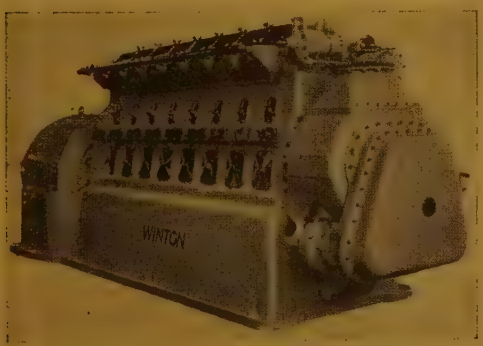
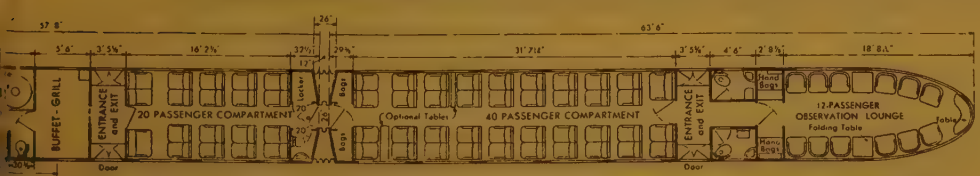


Fig. 6. — The Winton eight-cylinder, 600-H. P. two-cycle Diesel engine.

The main generator is a single-bearing, differentially wound machine placed forward of the engine and directly connected through a flexible steel-disc coupling. A direct-connected exciter is used for generator excitation purposes to give inherently the generator characteristic which permits full engine utilization over a wide range of train speed. A shaft extension is provided at the exciter end of the main generator to drive through V-belts a 25-kw. auxiliary generator mounted above the main generator. The opposite end of the auxiliary generator shaft is also extended for V-belt connections to the two fans which draw air into the engine room.

The two traction motors are mounted on the front truck of the leading car. They are series-wound motors of General Electric manufacture, having axle-



Burlington « Zephyr ».

bearing linings suitable for a 7 1/2-inch axle and a double nose for spring support on the truck bolster. The gearing is single reduction with a 25-tooth pinion and a 52-tooth gear. The armatures have SKF roller bearings and the axle bearings are of the sleeve type.

Fig. 7. — Looking into the engine room with the hatch and radiators removed.

The traction motors are self-ventilated by multiple fans mounted at the pinion ends of the armatures. Ventilating air is taken from the engine room through canvas ducts, and motor ventilation is aided by the slight positive air pressure — about 1 inch of water — in the engine room.

Motor control consists essentially of one master controller, electro-pneumatically operated motor contactors, and reverser, together with the necessary auxiliary magnetic contactors, switches, relays, etc. The control provides for operation from the front of the train only and for starting and stopping the engine, regulating headlights, cab lights, etc. The traction motors are progressively connected in series, parallel and parallel-shunted-field combinations with transfer from one connection to the next higher effected manually.

Photo by Wendell MacRae, New-York.

Fig. 8. — The operator's cab has clear vision through 180°. — Cooling air for the engine enters through the grilles over the cab ceiling.

The 25-kw. two-bearing 76-volt auxiliary generator is of the four-pole direct-current commutating-pole type. The output of the generator is furnished to the air compressors, the air-conditioning equipment, motor for train heating boiler, battery charging, lights, control, buffet utensils, etc., at a constant vol-

tage regardless of load, over a range of engine speed from idling to full speed, including engine regulation. This has been made possible by the combined effect of inherent regulation and the use of a new dynamic relay.

The storage battery is an Exide Ironclad 32-cell, 64-volt battery rated at 450 amp.-hr. at the 10-hour discharge rate, which is placed in a stainless-steel battery pit in the engine room. The weight of the battery is 3 260 lb. Ventilating scoops are used to increase air circulation in the battery box. The battery is used for engine cranking in addition to supplying power to the auxiliary circuits.

Two General Electric 25-cu. foot air compressors, driven by 76-volt motors, furnish the necessary air for the train. These compressors are of standard design, but with aluminum frame parts to obtain a light-weight equipment.

The trucks.

The four trucks are all of conventional outside bearing type of construction. All have cast-steel frames and bolsters, furnished by the General Steel Castings Corporation. Their combined weight is 55 000 lb. without the motors and gears in the power truck. The power truck, in which are mounted the two traction motors, has 36-inch wheels. This is the front truck and carries the weight of the power plant. The trailer trucks, although of the same general type, are considerably lighter in construction and run on 30-inch wheels. All journals are fitted with Timken roller bearings. The axles are hollow-bored to reduce weight.

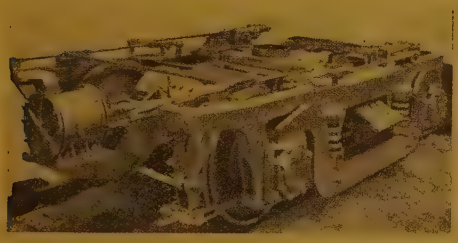


Fig. 9. — The power truck.

Fig. 10. — One of the trailer trucks.

Of particular interest in the construction of the trucks is the extensive use of rubber insulation to prevent the transmission of sound and other high-frequency vibrations to the car bodies. There are inserts under the center plate, in both top and bottom equalizer spring seats and between the ends of the equalizers and journal boxes. Rubber liners in the pedestals are faced with Oilite metal plates, vulcanized on, which serve as bearing surfaces for the faces and flanges of the boxes. The bolster pads, which insulate the bolster from the truck frame, are also faced with Oilite metal. In addition to the pad under the center-plate, rubber thimbles are provided around the king pin and the center-plate bolts, the latter also including washers. A further precaution against unnecessary noise is the provision of automotive brake lining wherever the members of the truck brake rigging are likely to rub. To dampen vibrations of lower frequency, Holland helical-volute springs are used on the equalizers of all four trucks. These springs consist of the conventional helical outer coil with an inner volute spring in place of the inner helical coil. The center plate

bearing, the bearing between the articulation castings and side bearings are all faced with Olite.

No two of the trucks carry the same load. With the train normally loaded the power truck is estimated to carry a weight at the rails of 98 000 lb.; the first trailer truck, between the first and second car bodies, 67 000 lb.; the second trailer truck, between the second and third car bodies, 45 000 lb., and the third trailer truck, at the rear end of the train, 30 000 lb. The nominal journal sizes are, respectively : Power truck, 6 inches by 11 inches; first trailer, 5 1/2 inches by 10 inches; second trailer, 5 inches by 9 inches; third trailer, 4 1/4 inches by 8 inches.

Brakes.

The train is fitted with Westinghouse SME-3 brake equipment, which has been modified specifically for high-speed articulated train units. This is a straight-air system with emergency feature and also has a brake pipe which permits standard automatic operation of the brakes in case it should be necessary or desirable to move this train in connection with steam-train equipment. There are three air lines on the train :

1. The emergency pipe through which the supply reservoirs for each vehicle are charged at all times under normal operation and the loss of pressure from which causes the control valves to effect an emergency application of the brakes.

2. The straight-air pipe, pressure variations in which cause the control valves to effect graduated service application and release, and

3. The brake pipe by means of which automatic operation of the brakes can be effected when the articulated train is moving in connection with steam-train equipment or when backing up and on which the conductor's valve in the rear car is placed.

The brake valve operates the brakes by controlling the pressure in the straight-air pipe. It is self-lapping, the degree of service application varying with the position of the handle, a feature by which great sensitivity is attained. The dead-man control is operated either pneumatically by a foot pedal or electro-pneumatically by a push-button on the brake-valve handle. The release of both of these automatically cuts off the power and causes an emergency application of the brakes. The brake valve also provides, electro-pneumatically, for an emergency application of the brakes should a failure of pressure in the straight-air pipe prevent a response to a movement of the brake valve to service application position within a predetermined time interval.

In order to effect the high rates of retardation required to keep stopping distances from speeds of 100 or more miles per hour within present limits, the brake system is designed for a 200 % braking ratio at 100 lb. cylinder pressure. Because of the increasing coefficient of brake-shoe friction as the speed is reduced, the brake-cylinder pressure is controlled automatically as the train slows down by a retardation controller, a pendulum inertia device by which brake-cylinder pressure is reduced at a rate sufficient to maintain a constant predetermined retardation rate. The retardation controller is wired in the battery circuit to solenoids on the control valves and through these the control of brake-cylinder pressure is effected.

Aluminum has been used extensively in the air-brake equipment in the interest of weight reduction. This includes the controlvalves and brake cylinders, etc. The supply reservoirs are of stainless steel.

The heating system.

The train is equipped with steam heating throughout. Each passenger compartment also has its own mechanical

air-conditioning system. These are interlocked with the heating system so that the force-ventilation feature of the air-conditioning equipment is available both winter and summer.

Steam for heating is provided by an oil-fired Peter Smith boiler with an evaporative capacity of 500 lb. per hour at a pressure of 85 lb., furnished by the Vapor Car Heating Company. This boiler is located at the rear end of the baggage room in the second car. Its operation is completely automatic and, in order

Fig. 11. — The Peter Smith automatic oil-fired heating boiler.

to reduce weight, the condensate from the radiators is returned to the 50-gallon feedwater storage tank. Storage is provided for 75 gallons of fuel oil.

The operation of the boiler is subject to three controls :

1. A water-level control.
2. A low-water control, and
3. A burner load control.

The water-level and low-water controls are of the electrode, commonly called spark-plug, type. The electrodes are inserted in a container or bottle which is connected to the boiler in the same manner as a water column. They are of three lengths. The lower end of the longest one corresponds to low-water level and the vertical distance between the other two marks the variation in water level within which the feed pump is controlled. Current at 110 volts, furnished by a small motor-generator set, passes from the electrodes to their grounded metal container through the water. If the water drops below the end of the longest electrode, the failure of the current acts to close the oil-supply valve and stop the burner motor. A variation of the water between the ends of the intermediate and short electrodes serves to cut the feed pump in or out.

If pressure in the boiler builds up beyond a predetermined point owing to a load insufficient to utilize all of the steam being produced, a pressure switch operates automatically to reduce the flow of oil to the burner and the speed of the burner motor, thus maintaining a flame which is little more than a pilot light until such time as the reduction in pressure restores the flow of oil and the speed of the motor fan to their full load amount.

Heat is supplied to the passenger compartments from two sources. A fin-tube coil in the evaporator unit of the air-conditioning system in each compartment supplies heat to the fresh and recirculated air passing through the units to the compartments. Steam is also supplied to a copper fin-pipe along the truss plank near the floor on each side of the compartment. The admission of steam to both radiators is controlled by motorized valves which are actuated by independent thermostats. A thermostat

for the control of the air-conditioner radiators is located on a deadlight panel near the center of each compartment about 5 feet above the floor. The thermostat for the sidewall radiators is placed near the floor and serves to bring these radiators into action automatically when the heat distribution from the air-conditioning unit is not sufficient to maintain a predetermined temperature at the floor.

A unique scheme has been developed for returning condensate from the radiators of the front and rear cars to the feedwater storage tank on the second car. Water from the radiator traps drains into small sumps, one on each of the two cars. As the water level rises in the sump, a float causes a relay to open a solenoid valve in the brake pipe, admitting air to the sump under regulated pressure and forcing the condensate through a separate return line to the storage tank. During layover periods the entire train can be heated by steam from the terminal supply. The heating and thermostatic controls are the product of the Vapor Car Heating Company.

Air conditioning.

Each of the three passenger compartments is served by a complete York mechanical air-conditioning unit of 1 1/2 tons nominal capacity. The compressors as well as the condenser and evaporator units are all located within the underbody below the floors of the coaches. The evaporators deliver air through the grilles in the bulkheads over the center doors into the compartments. Recirculated air leaves the compartments through filter-protected openings in the floor over the evaporator units.

The motors for operating the compressors and the evaporator unit fans were manufactured by the General Electric Company. A 7 1/2 H.P. A.C.-D.C. motor operates the two compressors and the condenser fans on the third car and a 3-H.P. D.C. motor drives the compressor unit and the condenser fan on the second car. For standby service when the main power plant is not in operation a tap from a 220-volt, 60-cycle terminal supply can be plugged in to operate the A.C. motor on the rear coach. This drives the two units on this coach and the D.C. motor becomes a generator which supplies current for reduced-capacity operation of the unit on the second car. The D.C. motors operate on 76-volt current from the head-end supply. Two 1/4-H.P. and one 1/3-H.P. motors drive the evaporator fans.

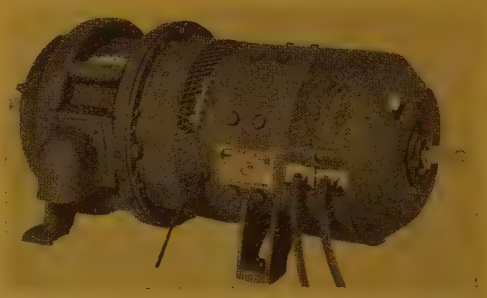


Fig. 12.— The General-Electric A.C.-D.C. motor set which drives the two air-conditioning compressors and condenser fans under the rear car.

The entire air-conditioning equipment has been designed with the requirement for light weight as a major objective. The evaporator units, including both steam and refrigerating fin coils, are aluminum. The compressor motors operate at 1 750 r.p.m. The complete equipment, including the motors and controls, has a total weight of about 2 400 lb., and with refrigeration lines, water lines, electric cables, etc., included, does not exceed 3 000 lb.

Copper pipe with sweated fittings has been used throughout the train for water, steam and air. Its use has effected a piping weight reduction estimated at 60 %. It is scale-proof and once installed possesses a high degree of permanence.

Because of the difficulty of access for replacement of some of the piping on the Burlington train, this factor was of considerable importance. Except for a few special fittings, no iron or steel pipe has been used.

Interior decorations.

The interiors of the passenger compartments in the Zephyr are all finished in pastel shades effectively used on the smooth wall surfaces without striping. The only ornamentation consists of the polished stainless-steel bands above the windows and along the ceiling at the open side of each lighting duct, and the stainless steel window sills. Each compartment has a distinctive color harmony to which wall colors, window drapes, upholstery and floor covering all contribute. In the smoking compartment the walls are finished in a pastel rose with golden rose window drapes. The seats are upholstered in leather medium brown in color. The floor is covered with Linotile with a dark mottled surface neutral in tone. The lavatory and buffet floors are covered with linoleum to harmonize with the Linotile.

Photo by Wendell MacRae, New York.

Fig. 13. — Looking toward the rear of the main passenger compartment from the smoking room. — The air-conditioner grille is over the door in the bulkhead.

The walls of the main passenger compartment are finished in a warm gray with a hint of green. The seats in this compartment are upholstered with Chase Velmo low-pile mohair. The color is gray-green with a gold background, the pile woven to form a striped pattern. The silk window drapes in this compartment match the green of the upholstery. The floor is covered with a plain taupe Chase Seamloc carpet. In the lounge the walls are finished in gray, in this case with a suggestion of purpleblue. The furnishings consist of comfortable lounge chairs and tables. The frames of the chairs are of scratch-brushed aluminum and the upholstery is of a purpleblue with gold background. The material and the pattern are similar to that of the seat coverings in the passenger compartment. The window drapes are of gold and the carpet is plain platinum-gray Chase Seamloc. The ceilings in all three compartments are finished in a light cream.

Furnishings.

The tables in the lounge are finished in non-blistering Formica of the same shade of blue as the upholstery. The side tables have drop leaves and are edged with filigree stripes of aluminum.

The window shades are of Pantasote with an inside fabric facing of a neutral two-tone pattern which harmonizes with the color schemes in all three compartments. The windows in the lounge are not shaded, except with the heavy silk drapes. The ouside surfaces of the window shades have an aluminum finish, which closely matches the unpainted stainless-steel exterior of the train.

In the smoking and passenger compartments the lighting is indirect, the lights being concealed within longitudinal ducts below the ceiling along each side of the car. The sides of these ducts toward the sides of the car are open and the light reflected from the curved inner surfaces of each duct and against the curve of the ceiling and the side of the car is diffused in a wide angle which reaches completely across the car at the reading height. The illumination on each side of the car is thus received from the lights in both conduits. The exterior of the conduit is blended into the surface of the ceiling by smooth flowing curves. The lighting is designed to produce an intensity of eight foot-candles at reading height. The lounge is lighted directly through diffusing glass which covers the underside of long ducts placed along the walls just above the windows.

The seats in the smoking and passenger compartments are built on lightweight aluminum frames. The height of the seat and the angle of the seat and back have been carefully chosen for travel comfort. The backs are adjustable from the normal upright to a semi-reclining position. They are built with a clear space 18 inches high underneath for the stowing of hand baggage. Facilities for holding overcoats and hats are provided by a metal rod and a spring clip fastened to the back of each of the paired chairs in the passenger and smoking compartments. Further storage space for luggage has been provided in racks on either side of the short passage at the front end of the rear car and also at the front end of the lounge. It has thus been possible to eliminate the conventional overhead racks for luggage and apparel and to preserve the motif of unbroken surfaces in the passenger compartments.

The train has a buffet which is equipped to supply grill service and to serve ice cream and both hot and cold drinks. It occupies a compartment 5 ft. 6 in. long across the center car. In the design of its equipment great ingenuity has been used to provide all of the necessary facilities, including ample refrigerator space, electric grills, urns for hot water and coffee, storage for dishes, cupboards for storage of foods, utensils, etc. Service may be provided either at the counter or at the seats in the passenger compartments. Removable trays, which can be bracketed between the seats, serve as dining tables. These trays are finished in black non-blistering Formica with aluminum filigree stripes on the edges. The dishes, which have been especially made for the train, are a deep cream color, each decorated with a single band of gold and with the Burlington emblem in colors. The plates have a 1/2-inch rim instead of the conventional 2-inch bevel to conserve storage space and to fit the service trays without crowding. Communication with the buffet from each seat is made possible by an annunciator. All passenger compartments of the train have radio reception from a Stromberg-Carlson 11-tube radio receiver.

Lights.

The front headlight is a 14-inch 250-watt, Golden Glow unit made by the Electric Service Supplies Company. The back-up light is a 9-inch, 40-watt unit made by the same manufacturer. The marker and classification lights are Pyle-National airplane-wing lights in housings made by the Budd Company. These lights are all built into the body of the train.

All lights inside the car and also all auxiliary apparatus are controlled through Westinghouse Nofuze load centers. Arrow, Hart & Hegeman heater switches provide for connecting inside lights all in multiple, for using only alternate lights and for dimming the lights by connecting the two groups in series.

Zephyr's place in Burlington passenger operations.

After a three weeks' tour of eastern cities, and a six weeks' tour of western cities, the Zephyr was placed on exhibition at *A Century of Progress* in Chicago. At the close of the Fair it will be assigned to turn-around service between Kansas City, Mo., St. Joseph, Omaha, Nebr., and Lincoln, on a four-hour schedule for the 251 miles.

The main idea back of the Zephyr is an effort to reduce the cost of passenger train operation, particularly that of the two- to five-car trains that are now handling head end and passenger business with little or no profit, and which produce 25 % of the passenger train mileage of the Burlington. At the same time, it is hoped that the train will have a sufficient appeal to the public to attract more business. With these objectives in mind, the Zephyr was designed especially to meet the conditions prevailing between Kansas City and Lincoln rather than as a train that can be used in any territory.

The distance from Kansas City to Lincoln is short enough so that an appreciable stepping up of train speeds will permit of a schedule that will give the passengers considerable time during business hours either before the beginning of the trip or after its termination. Because the bulk of the traffic of present trains is toward Kansas City in the morning, the Zephyr will leave Lincoln at about 8 a.m. and will arrive in Kansas City at noon. It will return during the afternoon of the same day. The schedule adopted will make it possible to eliminate two locomotives and six passenger train cars which equipment has a total weight equal to eight times that of the Zephyr.

The physical conditions of the route are such as to require only moderate expenditures to place the track in condition for high speed movements. The curvature and gradients are moderate; only 9 % of the curves are in excess of one degree and only 1 % are in excess of three degrees. Wye or loop tracks are available at both Kansas City and Lincoln on which the train may be turned around. High speeds between Kansas City and Omaha are favored, also, by the fact that there are only six highway grade crossings in that distance.

* * *

Leaving the Union Station at Denver, Colo., at 5.05 a.m. (Mountain time), on May 26, the « Zephyr » made a non-stop run of 1 015.4 miles to Halsted Street, Chicago, in 13 h. 5 m., or at an average speed of 77.5 miles per hour for the entire distance.

The fuel consumed on the run amounted to 418 gallons, the approximate cost of which was $ 16.

Not only were innumerable records broken during the course of the run, but also the dependability of the train and of the Burlington track were given a thorough and satisfactory test. The longest previous non-stop run, 401 miles, on the London Midland and Scottish Railway of England, was exceeded more than two and a half times, and all records for average speed for stretches of 200 miles and over were excelled.

Among the highlights of the speed records were the following :

Maximum speed attained : 112.5 m.p.h.

Yuma, Colo., to Schramm, 6.4 miles, 3 1/2 minutes, average speed, 109.0 m.p.h.

Otis, Colo., to Schramm, 19.1 miles, 11 minutes, average speed, 106.2 m.p.h.

Otis, Colo., to Mc Cook, Nebr., 129.5 miles, 86 minutes, average speed, 90.0 m.p.h.

To compensate for the slower speeds through the larger cities, it was necessary to traverse 215.7 miles at an average rate of more than 90 m.p.h., of which 19.1 miles was traveled at more than 100 m.p.h.

[621. 335 (.43) & 621. 43 (.43)]

German railcar with 330-B. H. P. twelve-cylinder Mercedez-Benz Diesel engine.

(*Diesel Railway Traction*, supplement to *The Railway Gazette*).

Fig. 1. — Fast railcar with 12-cylinder engine, German State Railways.

From the Daimler-Benz works at Stuttgart there has recently emanated a compact and light high-speed Diesel engine of the Mercedes type developing 330 B.H.P. at 1 700 r.p.m., the cylinder head and injection arrangements of which are based on those of the six-cylinder 135-B.H.P. engine built by the same firm, as shown in the accompanying cross sectional drawing. These smaller engines have started running in railcars belonging to the Reichsbahn early in 1933. The new engine weighs only 4 000 lb., or 12.1 lb. per B.H.P., and has an overall length of 5 ft. 7 in., a breadth of 3 ft. 4 in., and height of 3 ft. 7 1/4 in.

Twelve cylinders are arranged in two banks of six on a common crankcase made of silumin, and stand on this at an angle of 60° to one another. They are cast in blocks of three with detachable

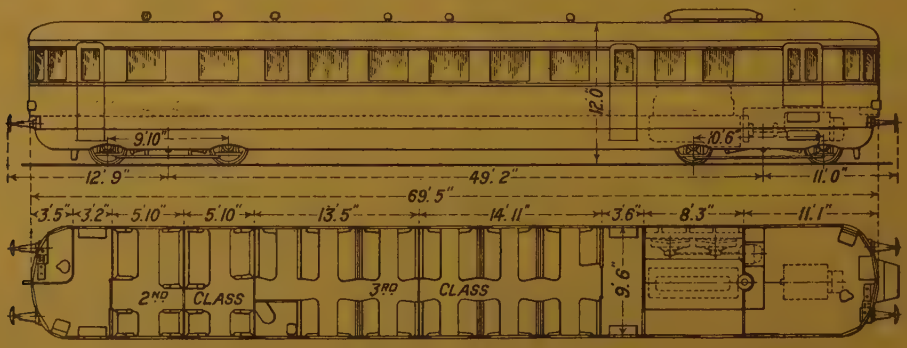


Fig. 2. — New Reichsbahn Diesel-electric railcar with 330-B.H.P engine.

heads, and the inlet and exhaust ports open inwards, that is, into the V of the two banks. The pushrod compartments of the blocks are on the outer sides of the engine, where are situated also the Bosch injection pumps, one for each bank of cylinders.

A crankcase of rigid design is provided, and is brought down below the level of the seven main bearings. The attached sump pan is deeply ribbed, and slants downwards towards the flywheel end, where the oil can collect in a recess. The six-throw crankshaft is in one piece, and is balanced as far as is possible without the use of counterweights. Bronze bearing shells lined with lead-zinc are used both for the main and big-end bearings, and to obtain a short engine, master and link rods have been provided, and the lower ends of the latter have Carobronze (phosphor-bronze) bearings on the master rods. The same bearing metal is also used for the connecting rod eyes. Light-alloy pistons with cast-iron ring carriers have been adopted, and the gudgeon pins are fully-floating.

There are two camshafts arranged one in each side of the crankcase, and they are driven from the forward end of the crankshaft by gears. The toothed ring of this gear is cushioned by a number of small coil springs arranged peripherally between it and the star-shaped hub piece. At this end the crankshaft carries a bevel gear driving an upright shaft leading to the governor, which is arranged in a casing between the cylinder blocks, and also a vibration damper, which is enclosed by the timing case cover. The timing case extends beyond the sides of the crankcase and contains on each side two further gears driven off the camshaft gears. The two lower of these gears drive water circulation pumps, one for each bank of cylinders, and the upper gears drive the Bosch injection pumps. The right water-pump gear also drives à 1 200-watt 24-volt dynamo clamped on the crankcase.

The cylinder blocks have wet liners of chrome-nickel cast iron, with a bore of 138 mm. (5.43 inches) and a stroke of 170 mm. (6.69 inches), giving a total piston displacement of 30.5 litres. Mercedes-Benz pre-combustion chambers are inserted in the detachable cylinder heads, in which the Mercedes patent atomiser is screwed. The precombustion chambers are inclined at about 35° to the cylinder axes, and stand near the outer edges of the cylinder heads between the two valves, which are arranged standing all in one line slightly inwards from the centre line of the cylinder bank. The valves are operated in the usual manner by pushrods and rockers. The latter are mounted on hollow shafts, which are supported by four brackets on each cylinder head. The whole valve mechanism on the cylinder heads is enclosed by light metal covers which leave a ledge on the inner side of the heads, where the water outlet pipes are fitted.

Dry sump lubrication has been adopted. A dual geared pump in the sump recess is driven by means of skew gear off the right camshaft, and the lower pump delivers the oil collecting around it to an external tank, into which it flows through a strainer. The upper pump draws the oil from the tank and delivers one part of it to the main bearings, and the remainder to the hollow camshafts and the hollow shafts carrying the valve rockers. From the main bearings the oil reaches the big ends, whence it passes up tubes fitted on the flanks of the master rods and up the hollow link rods to the gudgeon pins. A secondary oil line branches off the main distribution system to an external filter mounted on the left side of the crankcase at the forward end.

The flywheel of the engine is provided with teeth, which can engage with the pinions of two 12-H.P. electric starting

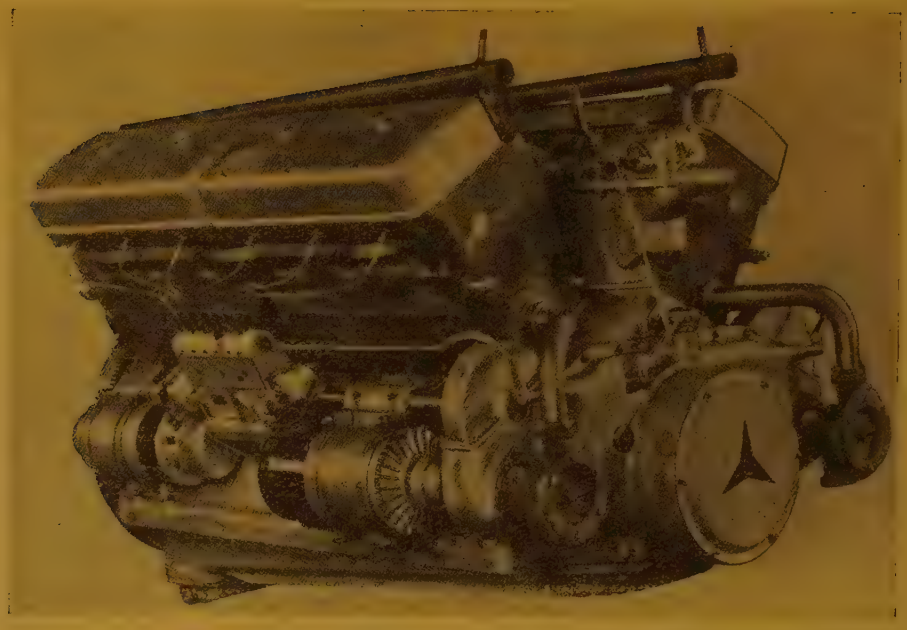


Fig. 3. — Mercedes-Benz 12-cylinder 330-B.H.P. railcar Diesel-engine.

motors fitted one on each side of the crankcase. To facilitate starting, heating plugs are fitted in the precombustion chambers at right angles to the injection nozzles, which are co-axial with the chambers. To free the bearings before starting, the exhaust valves can be decompressed by means of short pushrods standing on flat faces on shafts passing through the pushrod compartments of each cylinder bank. The governor is mounted on a horizontal shaft and controls idling and maximum speed, which latter can be regulated at the discretion of the driver, i.e., the governor will prevent the engine exceeding any speed that is desired. The forward end of the governor shaft can be provided with a slip clutch and fan if it is possible to mount the radiator immediately in front of the engine. The governor controls the fuel charges of both injection pumps through a transverse shaft passing through the timing gear case, with which it is connected by levers and a rod. The projecting ends of the transverse shaft carry levers, which are connected by rods with the plunger control racks in the pumps.

As such engines cannot usually be kept under the immediate observation of the drivers, electrical control instruments are provided on this Mercedes-Benz engine. Behind one of the injection pumps an electrical revolution counter is fitted, the current of which can be conducted to two or more dials conveniently distributed over the railcar. There are similar electrical thermometers and oil pressure gauges.

During tests conducted by the Reichsbahn the performance of the engine was so satisfactory, that the railway authorities ordered a number of them without awaiting the results of practical service. In the table given below the readings given under A are for the engine fitted with 1 200-watt dynamo running idle, with suction and exhaust manifolds, the latter water-cooled, but without silencer

and without fan. The B readings give the performance with dynamo, silencer and fan running.

R.P.M.	B.H.P.		B.M.E.P. (lb. per sq. inch.)			
	A.	B.	¼ Load	½ Load	¾ Load	Full Load
700	154	146	22.7	48.3	69.7	91.0
1000	232	220	25.6	51.2	72.5	96.7
1300	300	280	25.6	49 8	72.5	96.7
1500	336	310	24 2	47.0	70.0	93.8
1700	358	326	22.7	44.0	68.3	89.6

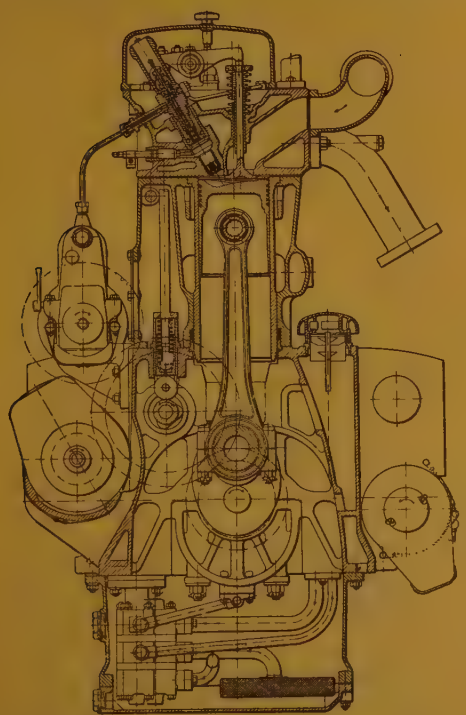


Fig. 4. — Cross section of 135-B.H.P. Mercedes-Benz engine as used in German railcars.

The engine develops its highest torque between 900 and 1 300 r.p.m., when it attains from 1 157 to 1 171 ft.-lb. At 700 r.p.m. the torque is 1 099 ft.-lb., at 1 500 r.p.m. 1 114 ft.-lb., and at 1 700 r.p.m. 1 042 ft.-lb. Fuel consumption is lowest at 1 000 r.p.m. when 0.425 lb. is used per B.H.P.-hr.; at 1 300 r.p.m. it rises to 0.429 lb., at 1 500 r.p.m. to 0.44 lb., and at 1 700 r.p.m. to 0.48 lb. per B.H.P.-hr. The lubricating oil consumption averages 0.018 lb. per B.H.P.-hr.

These engines are mounted in all-steel double bogie railcars weighing 50 tons, and seating 14 second-class and 52 third-class passengers in an overall length of 72 ft. 11 in. The engine, and its attached 200-kw. A.E.G. generator, are mounted directly on a bogie having a wheelbase of 10 ft. 6 in., and the two 106-kw. traction motors drive the 35 1/2-inch wheels of the remaining bogie, which has a wheelbase of 9 ft. 10 in. Roller bearing boxes are employed for all axles, and welding has been largely used in the construction of the body and underframe. The cars, which are shown in the illustration at the head of this article, and in the accompanying diagram, are virtually duplicate with those powered by 410-B.H.P. Maybach and 300-B.H.P. Motorenwerke Mannheim engines, which were described in the issues of the *Diesel Railway Traction Supplement of The Railway Gazette* for July 14 and October 6, 1933. Most of the cars, including that illustrated herewith, have been built by the Triebwagenbau A.G., of Berlin, and are fitted with Gebus electrical control.

MISCELLANEOUS INFORMATION.

[621. 134. 1 & 669]

1. — Duralumin connecting rods, French Est Railway.

(The Railway Gazette.)

In October, 1930, Mr. Duchatel, the Engineer-in-Chief of Material and Traction of the French Est Railway, decided to give a trial to duralumin as a substitute for steel for connecting rods, and to that end fitted a set of rods to one of the *Prairie* (2-6-2) tank engines working on suburban services. These locomotives have two outside cylinders 21 inches diam. by 26 inches stroke, with a piston thrust of 64 000 lb., and the duralumin rods were designed to take the place of steel rods without any modifications to the crankpins or other extraneous details.

A consideration of the detailed drawing presented herewith shows that the webs of the rod are of appreciably greater section than is found in a modern alloy steel unit of similar length and with a similar piston load, and that although the rod is not long, ample width is provided to prevent deflection in the horizontal plane. But due to the lower specific gravity of the material, the rod is 25 to 30 % lighter than an alloy steel rod designed for the same duty.

Several proposals to use duralumin rods on various railways have had to be turned down

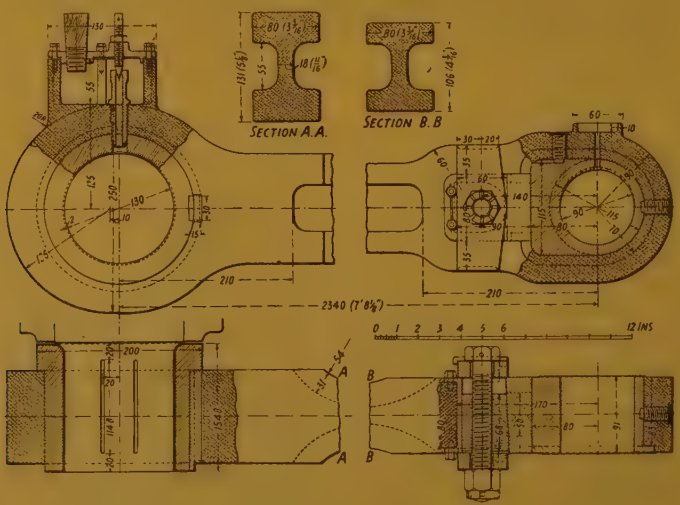


Fig. 1.

on account of the required width of the rod, especially with centre to centre lengths in excess of 9 feet or so, but no such trouble was experienced with the relatively short rods of the Est *Prairie* tanks. But the moments of inertia of 21.15 and 6.59 in the vertical and horizontal directions respectively are a good deal higher than are found in an average steel rod of similar overall proportions, due, of course, to the lower stress allowed with duralumin.

Big ends of the solid unadjustable type are employed, and the bush is of the railway company's standard bronze, with a white-metal

lining 2 mm. thick which extends over the whole bearing, and, with a thickness of 1 mm., over the end thrust surfaces also. The bush is prevented from turning by a steel key. The small end is of the adjustable pattern, with a plain bronze bearing.

Forged duralumin of the type used for connecting rods may have widely different strength characteristics according to the heat treatment to which it is subjected. An aluminium content of not less than 92 % is usually specified, and varies between that figure and 94 %, with 4 % of copper and 0.5 % each of manganese and magnesium. Normalising is effected by heating to 800° F., and, after several hours at this temperature, gradually cooling. Further heat treatment consists of raising the temperature to 950° F., maintaining this temperature for half-an-hour, and, after quenching in water, ageing in a normal atmosphere for a period of four to eight days. The ultimate strength is then 50 000 to 55 000 lb. per sq. inch, the yield point approximately 30 000 lb. per sq. inch, and the Brinell hardness number 95. A maximum stress of 10 000 to 11 000 lb. per sq. inch is allowed in high-speed oil engines, but the stresses found in the Est locomotive rods are a good deal below this figure. They are given in detail in the accompanying table, and it will be seen that the stresses are about 20 % lower than those found in alloy steel rods, except the inertia stress, which is 35 to 50 % lower. In getting out the values in the table, the Merriman formulæ have been used when considering the rod as a column.

After running 41 000 miles, the Est locomotive with the duralumin rods was, in October, 1932, involved in an accident, and was taken out of service. The rods were sent for repair and renormalising, but the works to which they were sent for treatment did not appear to notice that the blows which one of the rods had received in the accident had caused fissures to appear in the inside angles of the small end, and for this reason the rods have not yet been replaced in service. Until the accident the rods had given no trouble.

Particulars of duralumin connecting rods, 2-6-2 T locomotive, French Est Railway.

Material		Duralumin.
C.S.A. at centre of rod	sq. inches.	9.497
C.S.A. at small end	»	7.946
Moment of inertia about horizontal axis.		21.15
Radius of gyration about horizontal axis	Kv.	1.493
Moment of inertia about vertical axis.		6.59
Radius of gyration about vertical axis	Kh.	0.833
Section modulus about horizontal axis		9.07
Section modulus about vertical axis		4.188
Weight of rod = average C.S.A. × L × 0.102.	lb.	95.0
Length of rod, centre to centre, L.	inches	92.1
Unit stress at centre.	lb. per sq. inch	6 745
Unit stress at small end	» »	8 055
Unit stress at centre at wheel-diam. speed	» »	2 245
Ratio L/Kv.		61.7
Ratio L/Kh.		110.7
Vertical stress (Merriman)	lb. per sq. inch	7 400
Horizontal stress (Merriman)	» »	7 220
Load to cause buckling, vertical plane	» »	22 000
Load to cause buckling, horizontal plane	» »	22 800
Factor of safety, vertical plane	» »	2.98
Factor of safety, horizontal plane	» »	3.16
Inertia stress at wheel-diameter speed	» »	2 520
Vertical stress at wheel-diameter speed	» »	2 300
Combined vertical and inertia stress	» »	4 820
Piston load	lb.	64 000

[621. 335 (.489) & 621. 43 (.489)]

2. — 1 100 - B H.P. Diesel-electric high-speed train units for the Danish State Railways.

The firm of A. S. Frichs, Aarhus, has recently received an order from the Danish State Railways for four express train units.

The new trains are designed as Diesel-electric trains, each consisting of three cars, i. e. two motor cars at the ends with one ordinary car between them as shown on figure 1.

In order to diminish the air resistance during the run, these trains will be built on the streamline principle, and so as to avoid eddying under the carriages, they will be provided with a sheet-iron apron, which comes as near the rails as possible.

Besides the car bodies, the train consists of two bogies for the Diesel engines and two for the electric traction motors. The Diesel engines, the cooling plant, the complete engine room, the electric equipment, bogies, brake equipment, etc., will be delivered by A. S. Frichs, whilst the actual car bodies will be delivered by A. S. Scandia.

The most important technical data are as follows :

Weight in working order	118 t. (116.1 Engl. tons).
Length over buffers	63.68 m. (208 ft. 11 in.).
Outside overall width	2.86 m. (9 ft. 4 19/32 in.).

In the front end there is a driver's cabin joining the engine room, which contains one set of the Diesel engines. Then follows the restaurant, which is separated from the engine room by a double sound-resisting partition, and has seating accommodation for 13 passengers. Next comes the first part of the passenger compartment, i. e. the so-called « mutual » (or common) class compartment with 52 seats consisting of high-backed, leather-covered settees arranged in rows in the normal way, two seats being provided on each side of the middle gangway.

The middle carriage of the train contains eight compartments. The two extreme compartments in this vehicle belong to the mutual class, while the six middle compartments are 1st-class with room for six passengers in each.

As the luggage room can be equipped with the furniture from the restaurant, the train is completely symmetrical and has thus, in reality, neither front- nor rear-end, and each train has seating accommodation for 156 passengers.

The power plant consists of four Diesel engines directly connected to four. D. C. generators with belt-driven exciters and four D. C. series-motors, each driving one set of wheels through a reduction gear.

The Diesel generators are arranged two by two on each engine bogie, whilst the four traction motors are mounted on the two other bogies.

At each end of the train there is a driver's cabin provided with the necessary adjustment and control apparatus, the whole power plant being thus controlled from either end of the train.

The train also carries a battery of accumulators for starting the Diesel engines; this, together with the exciter, delivers the necessary power for the auxiliary machinery and lighting of the train.

The auxiliary machinery for each set of Diesel engines consists of an electrically-driven air compressor delivering the necessary air for the compressed air brake, control-, signal- and sanding apparatus, together with an electrically-driven cooling water pump.

Bogies.

The engine bogies consist of reinforced plate iron frames resting on the two axles with the wheels inside of the frames. The Diesel generators are mounted on top of these plate iron frames.

The motor bogies have also two sets of wheels like the engine bogies, and are provided with two traction motors and two centre pieces in the transverse reinforcement of the bogie.

Fig. 1.

The wheels and axles have roller bearings and are fitted with shrunk-on tyres of special steel, with a breaking stress of 90 kgr./mm² (57.1 Engl. tons per sq. inch).

An automatic compressed-air brake and a hand-controlled oil pressure brake, which can be worked from either of the driver's stands, is provided. The brakes operate on both sides of the brake drums on all the axles.

The brakes are designed for direct as well as indirect braking, with a braking capacity of 85 % of the tare weight at indirect braking.

Furthermore, an electro-magnetic rail brake is proposed in order to shorten the braking distance.

The sanding devices are arranged in such a way that the sanding takes place in front of each bogie in both directions. The sanding gear is controlled from the driver's brake handle, and through a compressed air system, operated by means of electric switches in each driver's cabin. The sanding also takes place automatically when the emergency brake is pulled.

The Diesel engines are of Frichs standard type 6185 C. A., 6-cylinder, single-acting, and with solid injection, operating on the 4-stroke-cycle principle and are completely enclosed.

The engines are designed for three different speeds, i. e. 475, 850 and 1 000 r.p.m.

All valves and parts needing frequent inspection, are easily accessible and can be exchanged without difficulty.

In order to obtain the highest strength with a minimum weight, all the working parts have been made from special material.

Each cylinder has an exchangeable cylinder liner made from special cast iron, together with special cylinder heads with fuel injection, inlet and exhaust valves.

The fuel oil supply, and the revolutions of the engines can be regulated automatically in order to enable controlling from either end of the car.

The engine is pressure-lubricated by an oil pump, driven in the ordinary way directly from the engine, the oil being thus pumped directly to all moving parts.

Ribbed tube radiators on the roof, cooled by means of a powerful electrically-driven fan, provide the cooling water for the Diesel engines. The whole cooling plant is laid out in such a way as to use to the best possible advantage the whole of the effective cooling surface, and it is of such dimensions that the temperature of the cooling water does not exceed 60° C. (140° F.). The temperature of the cooling water can be ascertained from both driver's cabins by means of a pyrometer. The cooling water is circulated by means of electrically driven centrifugal pumps, which drive the water from the cooling water tanks through all the jackets to the radiators, whence it returns to the tanks.

The electrical plant.

The generators are shunt dynamos excited from an outside source, provided with reversing poles and main current starter winding, and directly connected with the Diesel engines, so that they can be dismantled and removed independently.

Each generator has an output of 200 kw. continuous rating, at 720 volts and 1 000 r.p.m. The generators can, for starting, stand for a short time a load of 500 amperes.

The auxiliary dynamos are placed on top

of the main generators and are driven from the latter by means of three V-shaped rope belts with tightening rollers. The windings are designed for 100/150 volts, 75 amperes, and are supplied with a weak differential compound winding and provided with a variable resistance from the shunt circuit in such a way that they can charge the battery at all three speeds of the Diesel engines.

Traction motors.

The traction motors are self-ventilating series motors, and are of the strongly protected type. Easily removable covers are provided at the commutator end to enable inspection of the motors. Each traction motor has an output of 160 kw., continuous rating, at 720 volts and 1 500 r.p.m. They are regulated in the normal way by means of the generator voltage and the field resistance.

Each driver's stand contains the necessary apparatus for starting and stopping each of the four Diesel engines, and a handle for forward and reverse driving, which at the same time controls the speed of the Diesel engines and the voltage of the auxiliary generators, thus enabling of the battery being charged at all three speeds.

In the driver's cabin are also to be found control lamps for the cooling water and lubricating oil pressure, together with pyrometers for the cooling water, a speedometer and the brake controlling devices.

In accordance with the regulations, a dead man's pedal has been installed in connection with a dead man's handle. The driver can thus leave the pedal if, for some reason or other, he wants to look out of the side window, provided he at the same time keeps the button on the dead man's handle pressed down.

The accumulator battery consists of 58 cells with a capacity of 258 amp.-hours at a five-hour discharge. The battery is used for starting the Diesel engines and for lighting purposes, as well as for driving the auxiliary machinery when the Diesel engines are not working.

[621. 43 (.492)]

3. — 72/85-B.H.P. Dutch Diesel-electric tractors.

(From *Diesel Railway Traction*, supplement to *The Railway Gazette*.)

In addition to the 40 high-speed Diesel trains, the Netherlands Railways recently ordered 13 Diesel loco-tractors, and these are now in course of delivery. Two years ago, Stork Bros., of Hengelo, delivered two four-weeled machines with 145/160 B.H.P. eight-cylinder Ganz-Jendrassik engines running at 1 000 r.p.m., and one of them is illustrated at

Fig. 1. — One of the first two Diesel-electric loco-tractors of the Netherlands Railways Thirteen similar machines are now on order.

the head of this article. The results obtained with these units decided the railway authorities to extend the practice, but the new tractors are only of 72/85 B.H.P., although, like the two 160-B.H.P. machines, they incorporate electric transmission.

The engines are of the Ganz-Jendrassik type, built under licence by Stork Bros., and have four cylinders with a bore of 150 mm. and a stroke of 185 mm. At the rated speed of 1 000 r.p.m. the brake m.e.p. is 83 lb. per sq. inch, and the piston speed 1 215 ft. per min. A pre-combustion chamber is employed, but the atomiser nozzle has an opening of slightly more than one millimetre in diameter, so that no trouble through fouling or choking is anticipated. Owing to the relatively large nozzle, the fuel velocity is low, and this results in less wear of the affected parts. The fuel is forced through the bottom of the pre-combustion chamber to a cam-shaped projection on the cylinder crown, from which the fuel is sprayed in all directions. This projection prevents the fuel jet impinging directly on the flat surface of the piston crown.

A Ganz fuel pump of the spring injection type is fitted, and ensures an atomisation of constant high efficiency over the full speed range, a matter of some importance at starting. The injection pressure is approximately

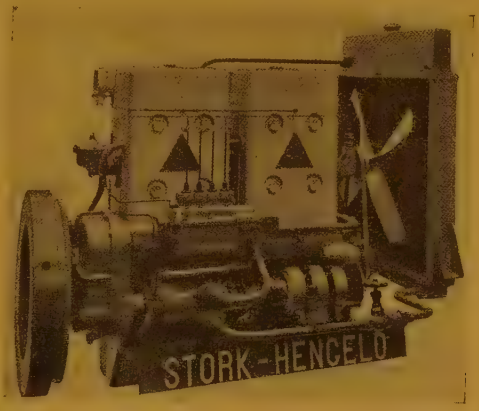


Fig. 2. — 72/85-B.H.P. Stork-Ganz oil engine.

1 150 lb. per sq. inch. A start from dead cold can be made, without the use of pre-heating or an ignition coil, by opening the air valve only towards the end of the suction stroke.

[656 (.42)]

4. — Railways and aviation.

Possible consequences of joint action with Imperial Airways,

by T. STANHOPE SPRIGG.

(Modern Transport.)

The announcement that the four railway companies are to co-operate with Imperial Airways, Limited, in the development of internal airways came as no surprise to those in touch with air transport. Indeed, it had been obvious from the time the Great Western Railway Company inaugurated the first railway-operated air service last year that air transport was an activity in whose development the four railways would have to co-operate according to a planned scheme, and it was a foregone conclusion that they would go for technical assistance to the only long-established air transport undertaking in this country, namely, Imperial Airways.

Imperial Airways has for some time been divided for administrative purposes into two services — the Commercial Service and the Operations Service. The commercial side is concerned with finding and handling the payload, and the scope of this definition includes traffic management, the provision of ground transport, catering for passengers, accountancy, and freight collection and delivery. The operations service is concerned with the provision of aircraft as and when required by the commercial side, and this includes responsibility for airframe and engine upkeep and repair, organisation of pilots and ground engineers, and the like. It is obvious that the new

company will have a similar division, and in this case the commercial service will be provided by the Railways, and the operations service by Imperial Airways. Experience has proved that such a division is vital for the successful operation of so highly technical a business as air transport.

Immediate effects.

It is difficult at this stage to predict the full effect of the new group on internal aviation. The immediate effect will be to impart at once much higher standards of safety and organisation into short-distance air transport. In this connection three examples may be taken. The first is the pilot, and Imperial Airways' standards are more rigorous in this respect than the average air transport undertaking, which tends to assume that what is good enough for the Air Ministry is good enough for them. That is to say, they take the « B » license as an acceptable qualification. Imperial Airways demand, however, in addition to a « B » licence, 1 000 hours' experience of multi-engined types, a second-class navigator's certificate, A and C ground engineer's licences, and a wireless operator's (air) licence.

Even so, such a pilot has to serve for a period as first officer, that is, as assistant pilot. Another example that may be taken is the machine. Imperial Airways have as their minimum the machine with three engines, and now favour the four-engined aircraft. They would not contemplate what internal operators are doing in this country to-day, that is, flying over 70 miles of water with twin-engined machines which have a theoretical ceiling of 1 000 feet fully laden when one engine is out of action. Radio may be taken as a final example, and in this connection it is doubtful if Imperial Airways would be prepared to operate over a route of any length without wireless facilities except as a temporary expedient.

Possibilities of licensing.

These more rigid standards obviously involve greater expense of operation, and lead one to speculate as to what will be the outcome of the railways' venture. Experience has shown that where two air lines run side by side, with differing standards of safety and organisation, the public will travel with the cheaper, in spite of the lower level of organisation. It has, in fact, become almost an axiom in the transport world that the public has to be protected against itself. The railways could afford as a temporary measure to run their air services competitively at a loss, but such a state of affairs cannot be permanent. A second difficulty that will arise is common to all spheres of competitive transport. There will be in internal air transport certain well-paying routes, equivalent to the London-Paris route on the cross-Channel airways, and the competition on these will be keen, reducing the profit margin to the bare minimum. There will, therefore, be correspondingly less inducement for a group to embark on the more experimental routes which at first will carry little traffic.

The situation will not be very different to that which obtained recently in road transport, and the solution will presumably be the same. There will be a demand for licensing and perhaps for the establishment of much more rigourous standards for equipment and personnel on licensed air lines, corresponding to those adopted by Imperial Airways. It may seem early days to be talking about licensing air transport operators, in view of the fact that two years ago there was only one in this country, but events have moved rapidly since then. In little more than twelve months the outlines of an internal air transport system heve become apparent, large interests have entered the field, much capital has already been invested, and the growth shows no signs of ceasing.

Need for unification.

There is, of course, no reason to suppose that air transport in Great Britain need be a monopoly. The regular air service shades off almost imperceptibly into the private charter or air-taxi operator, and the latter is essentially an individualistic organisation, but if the past history of transport has proved anything it has shwon that the only alternative to complete chaos is some unification of

operating standards and the elimination of wasteful competition. This can perhaps best be achieved by the licensing of services.

An alternative might be to use the allocation of air mail contracts (which will undoubtedly be a feature of internal air transport in the future) as a means of discrimination. Only those services complying with minimum standards of organisation could be selected as contractors and not more than one contractor for each route. The revenue from mails might enable the contractor to lower the cost of passenger fares, in spite of higher operation costs. But the scheme has obvious disadvantages, and some measure of direct control of the air transport industry may be nearer than is generally supposed.

CORRIGENDUM.

BULLETIN, July 1934.

Article headed : « **New design of carriage bogie on the J. G. Brill system** », pages 755 to 759 :

Instead of « **J. G. Brill Company** », the name of the manufacturing firm should read : « **Compagnie J. G. Brill** » throughout this article.

NEW BOOKS AND PUBLICATIONS.

[385. 1 & 657.]

FALLET (Edouard-M.), Doctor of Commercial and Economic Sciences. — **L'amortissement industriel dans les compagnies de chemins de fer** (*Commercial amortisation applied to railway companies*). — One volume (9 1/4 × 6 7/16 inches) of 224 pages. — 1933, Neuveville, Imprimerie W. Henry. Sold by the author : 13, rue Fritz Courvoisier, at La Chaux-de-Fonds (Switzerland).

The question of commercial amortisation is one of especial interest to the railways at the present time. Much of the rolling stock has had to be renewed and still more will have to be. In addition, the rental value of some of the lines is no longer certain and considerable adjustments in the capital value may be necessary.

The author has made a very thorough study of the position of a number of railways as regards commercial amortisation and has collected the necessary data from the best informed sources.

He begins by considering the theory of commercial amortisation; he shows why it is necessary and discusses the various methods of applying it in practice. This part of the book is a sort of foreword, trough it must be admitted that the subject is dealt with in some fulness.

The first part of the book deals with the bases of the theoretical application of commercial amortisation to railways. The bases are : the analysis of the sinking fund accounts, and the evaluation of the railway's locked up capital, the main causes of the devaluation of the capital account.

The second part shows how the problem of commercial amortisation has been dealt with in different countries. The methods adopted by the French Railways, the German State Railways, the English Companies and the Belgian National Railways Company are described. A historical review of the way the question has been treated in the U. S. A. and the relations between the Companies and the Interstate Commerce Commission in the matter are dealt with in the last chapter.

The author concludes by insisting upon the need for taking an inventory of the immobilised railway capital, the steps taken in this direction in America being described in the book.

As to how amortisation is to be done, he prefers the system of sinking fund and renewal fund accounts of the English Railways and recommended in part by the Interstate Commerce Commission as being very clear from an accounts point of view, besides being mathematically exact.

E. M.

[621. 138.5 (.43) & 625. 26 (.43)]

Dr.-Ing. h. c. Peter KÜHNE, Geheimer Baurat, Reichsbahndirektor und Mitglied der Haupverwaltung der Deutschen Reichsbahn Gesellschaft. — **Die Bedeutung einer planmässigen Erhaltungswirtschaft beim Fahrzeugpark für die Deutsche Reichsbahn** (*The importance, from the point of view of the German Reichsbahn of well organised rolling stock maintenance methods*). — Pamphlet No. 5 of the series of monographs « 3. Studienkonferenz der Deutschen Reichsbahn-Gesellschaft » (Third study conference of the

German State Railway Company). — A pamphlet of 56 pages with 11 figures. — 1933, published by the Verkehrswissenschaftliche Lehrmittelgesellschaft, m. b. H., bei der Deutschen Reichsbahn, Vosstrasse, 6, Berlin W. 9. (Price : 2 Reichsmark.)

This pamphlet, a continuation of the author's comprehensive work on the subject (1), was issued in the series of monographs prepared in connection with the 3rd study conference of the Reichsbahn. It gives a brief account of the important question of repair work organisation.

The rolling stock and mechanical equipment of the Reichsbahn are valued at about one third of its capital. Their maintenance absorbs considerable sums, one seventh of the total expenditure of the German Reichsbahn going on repairs and maintenance. Now, the repairs organisation endeavours to get the maximum output with the money put at its disposal. The result has been that after ten years of scientific development, thanks to administrative measures, improved technical equipment, and other rearrangements, the periods required for rolling stock repairs have been considerably reduced, while at the same time the quality of the work has been improved.

At the same time as the technical and administrative methods relating to repairs have been improved, the financial side of the workshops service has been reorganised. This great reform has resulted in the abandonment of the old administrative system in favour of a methodical and practical organisation. In this connection the author gives detailed explanations on the use of data supplied by the accountants and its influence on the work for which the maintenance department is responsible.

This pamphlet will undoubtedly throw light on many points not clearly appreciated, not only by railway officials but by economists and industrialists interested in the repair work on the Reichsbahn.

(1) Kühne, Peter, Dr.-Ing. h. c.: « Erhaltungswirtschaft bei der Deutschen Reichsbahn » (Repair work organisation on the German State Railway Company). Economical maintenance of locomotives and rolling stock, machine, tools and point and crossings in the repair shops of the German State Railway Company. 558 pages with 10 separate plates, 220 figures and plans of the 7 repair shops of the Reichsbahn. Preface by Dr. Dorpmüller, the General Manager. Berlin, 1933, same publisher.